533. f 22.
5

AN INTRODUCTION TO LATITUDE, WITHOUT MERIDIAN ALTITUDES; AND LONGITUDE, AT SEA;

HAVING

COTEMPORARY OBSERVATIONS:

WITH

ASTRONOMICAL DELINEATIONS

AND

NAUTICAL FORMULAS,

ENGRAVED on COPPER PLATES.

By SAMUEL DUNN;

Teacher of the Mathematical Sciences, LONDON.

LONDON;
Printed for the Author, at No. 1. Boar's-head Court Fleet-ſtreet.
MDCCLXXXII.

AN
INTRODUCTION
TO
LATITUDE,
WITHOUT
MERIDIAN ALTITUDES;
AND
LONGITUDE,
AT SEA, &c.

By S. DUNN.

SECTION I.

Of the *Logarithmic Solar Tables* and *Natural Sines*, which are commonly uſed in finding the Latitude; having two Altitudes and the Elapſed Time.

THE Method of finding the Latitude at Sea without taking Meridian Altitudes, affords ſo many opportunities, and at the ſame time is of ſuch uſe in finding the Longitude at Sea, in each of the methods that are practicable; that it is now conſidered as no inconſiderable part of Nautical Aſtronomy, and therefore, hath been much attended to of late years, in order to perfect this part of the Art of Navigation.

The Method which hath been generally practiſed, hath for its Data, the Ship's Latitude by Account, two Altitudes of the Sun's Center taken at proper times of the Day, the Solar Time Elapſed between the obſervations, and the Declination of the Sun, ſuppoſing it to be nearly the ſame at both times of obſervation.

The Tables by which calculations in this method have been commonly made, are Logarithmic Sines, and Secants leſs Radius, Common Logarithms and their Numbers, Natural Sines and their Arches; together with the Logarithmic Solar Tables, containing Logarithms of Half Elapſed Time, Middle Time and Riſing, to every 30 Seconds of time from 0 to 6 Hours. Theſe Solar Tables were conſtructed by Mr. Cornelis Douwes of Amſterdam, about 40 years ſince.

When theſe Solar Tables were firſt printed in this kingdom, the Logarithms of Numbers, Sines, and Secants leſs Radius, alſo the Natural Sines, were omitted; and that defect was ſupplied, by ſhewing how to find the Natural Sines from the Logarithmic Ones and their Numbers. In 1771 Mr. N. D. Falck publiſhed all theſe Tables together. The Nautical Ephemeris 1771 contains theſe Solar Tables improved to every 10 Seconds by Capt. John Campbell; reviſed from the Preſs by me.

In finding the Latitude by this method, the two Obſervations muſt be made "between Nine in the Morning and Three Afternoon," a number of particulars are to be remembered to know when the Data are under the moſt favourable circumſtances, and then only, "the error in the Computed Latitude, will not be above a fourth part of the Difference between that by Computation and the Latitude by Account".

In this Method; one, two, or more Operations are to be made as the caſe requires, and in each Operation there will be ten applications to the Tables; namely, twice for Natural Sines; twice for Secants leſs Radius; once for the Logarithm of a Number; once for the Log. of Half Elapſed Time; once for Hours, Minutes and Seconds in Middle Time; once for Log. of Time from Noon or Log. Riſing; once for a Natural Number after ſubtracting Log. Ratio: and once for Degrees and Minutes of Meridian Altitude. Of theſe ten ſteps, three require Proportional Parts which are not in the tables; two require care concerning the Index. Beſides there are together ſix Additions and Subtractions in each Operation; and in a ſecond or third Operation, only three Logarithms and one Natural Sine are uſed, the ſame as in the former.

The Number of theſe Steps and their Variety, has without doubt, been the cauſe of this Method having not been much more practiſed than it has, ſince its firſt publication. If the Solution of a Problem be by a continued Proceſs, whithout turning to Tables, or working for Proportional Parts, the Computor will ſoon become ready at it, and get an Anſwer with Certainty and Eaſe, which he will take more time about, in taking the ſame number of Figures from different Tables, working Porportional Parts, and placeing numbers through the Proceſs in a manner not eaſily to be remembered.

It is farther to be noted, that the greateſt Interval of Time between

tween the two Obſervations is to be no more than 6 Hours, in which Time, the Sun's Declination near the Equinoxes, alters near 6 Minutes of a Degree; and as there is no proviſion for this or any other Change of Declination in thoſe Tables, an Obſerver may err ſo much in determining the Latitude by them.

From what hath been here premiſed, the following inferences may be drawn concerning the Logarithmic Solar Tables, and their uſe.

1ſt. They are applicable, only between Nine in the Morning and Three Afternoon. The Limits of this Interval, may not be eaſily determined at Sea.

2d. They have no proviſion for the Change of the Sun's Declination. This, in uſual caſes may ſubject the concluſion to an Error of ſeveral Minutes in Latitude.

3d. The number of Figures in the Solar Tables, together with the Natural Sines to be uſed with them, in their beſt ſtate; amounts to near Seventy five Thouſand. This is near four Ninths of the number of figures, contained in all the Log. ſines, Tangents and Secants, to the ſame number of Places; theſe latter are the General Tables for Practical Aſtronomy.

4th. The Variety ariſing in the Application of the Solar Tables, both for the Latitude and in the contrary Problems to which they may be applied, is great; and the Precepts numerous. The Intricacies ariſing from a manifold Variety in Computations, cauſe Difficulties and Error; the fewer the Precepts are, the better they may be applied; the more numerous they are, the greater need of Judgement and Remembrance; and where both of theſe fail, or the Precepts are not at hand, the Computor cannot work out the Obſervations.

5th. It was Neceſſity and an entire Inability in Mathematicians to anſwer the ſame end by any eaſier way, that induced them to eſtabliſh the Solar Tables. This is evident from the Nature of the Subject. 1. A Method by the Common Tables, as eaſy as by the Solar Tables, and extending from Nine in the Morning to Three Afternoon, is at leaſt as good as that by the Solar Tables. 2. A Method by the Common Tables, extending to any number of Hours; correcting, at the ſame time for the Change of the Sun's Declination, and eaſier in Calculation than by the Solar Tables; is far preferable to the Method by them. 3. A Method by the Common Tables, which contains all the forementioned Caſes, and at the ſame time, ſolves thoſe Difficulties without a Watch; and is much farther applicable, in ſuch Parts of Nautical Aſtronomy as are moſt wanted; is much beyond what can be ever expected from the Logarithmic Solar Tables.

6th. Such a Method as the laſt mentioned, is in this Work.

SECTION II.

Of a *General Method*, whereby the Latitude may be found, having any Two Altitudes of the Sun and the Time between the Obſervations; without the knowledge of Spherical Triangles.

"In a Treatiſe on *the Theory and Practice of the Longitude at Sea*, publiſhed in May 1778, I gave a ſpecimen of a General Method, whereby the latitude may be determined, by having *any* two Altitudes of the Sun, the Elapſed Time between the two Obſervations correctly meaſured by a Watch or any other Time-keeper, the Sun's Declination and the Latitude ſomewhat near the truth, as it is commonly known by the Reckoning of a Ship at Sea; the Calculation being eaſily made by the common Logarithmic Tables without any conſideration of the Properties of Spherical Triangles. But as the Method was there delivered in a conciſe manner, I drew up an account of the Principles on which it depends, to obviate any difficulties that might ariſe in the application of it either by Sea or Land, and publiſhed in July the ſame year; part of which is as it follows.

When an Obſervation is intended to be made the Quadrant or Sextant ſhould be adjuſted as correctly as poſſible, and the Watch or other Time-keeper by which the Elapſed Time is to be meaſured, ſhould be brought to ſuch an equable rate of going, that it may be depended on for meaſuring the Interval of Solar Time, very near the truth. Nor ſhould either of the Altitudes be taken when the Sun is very near the Meridian, eſpecially when the place of obſervation is remote from the Equinoctial, becauſe then the Sun's Altitude changes ſlowly; but at any other times of the day the two Altitudes may be taken, allowing as uſual for the Dip of Horizon, Refraction, and Semidiameter when the lower limb is brought to ſweep the Horizon of the Sea.

The Elapſed Time meaſured between the two Obſervations may be about an Hour, or leſs will be ſufficient in caſes where it is meaſured accurately, and the two Altitudes are taken with but very little error; otherwiſe, a longer Interval may be more advantageous for an accurate determination of the Latitude. But when ſuch Interval is long, and the Sun's Declination changes from one to two or three Minutes of a Degree, between the Obſervations, the Declination and Polar-diſtance found therefrom, ſhould be taken out for both of the times of Obſervation as correctly as poſſible.

Under theſe circumſtances, it will not be neceſſary to know whether the two Altitudes are taken one before and the other after

Noon, or both before or both after Noon, if they are made on the ſame Day; becauſe, the two Hour-angles or Diſtances of the Sun from Noon at the times of obſervation, being computed (in uſual caſes) when the Sum of them agrees neareſt with the meaſured Elapſed Time, the Obſervations will have been made, one of them before and the other after Noon; but otherwiſe, when the Difference of them agrees neareſt with the meaſured Elapſed Time, they will have been made both before or both after Noon.

It is farther to be noted, that during the Elapſed Time, the Ship may have ſo altered her Place by the Courſe and Diſtance ſailed, that when the ſecond of the two Altitudes is taken, it will diſagree with an Altitude that would be taken that ſame Inſtant at the Place where the firſt Obſervation was made, from which Place the Ship is removed. This muſt be allowed for, thus.

1ſt. If the Ship had ſailed directly toward the Sun, the Miles ſhe hath ſailed in the Interval are the Minutes of a Degree to be ſubtracted from the Altitude at the ſecond Place to reduce it to the firſt.

2d. If directly from the Sun, they are to be added.

3d. If directly at Right Angles to either of the former Courſes, nothing is to be added nor ſubtracted.

4th. If on any other Courſe, the Subtraction or Addition is to be made, of as many Minutes as the Courſe and Diſtance in the Elapſed Time hath either carried the Ship toward or from the Sun, from the firſt to the ſecond Obſervation.

Theſe things being attended to concerning the Data or things given, the Obſerver will be provided with Five Things; namely, the two Altitudes each in Degrees and Minutes, the Elapſed Time turned into Degrees and Minutes by allowing 15 Degrees to an Hour of Time, the Sun's Declination and conſequently his Polar-diſtance, the Latitude by the Reckoning imperfectly known, to which he is to add a Sixth thing given; namely, another latitude greater or leſs than that of the Reckoning, at Diſcretion, as he may judge the Latitude by the Reckoning to be either erroneous or uncertain; and from theſe, the true Latitude may be found by the following Method of Computation.

Former General Rules for computing the true Latitude, having the Latitude by Account, two Altitudes and the Elapſed Time.

1ſt. With the Co-latitude by the Ship's Reckoning, the Polar-diſtance and each of the two Co-altitudes, compute the two Hour-angles from Noon for the two times of Obſervation, and their Sum or Difference (that of the two agreeing neareſt with the Elapſed

Elapſed Time) will be the firſt proof that the Latitude by the Reckoning is either true or erroneous; for if it be true, it will be the ſame as the Elapſed Time; otherwiſe it will be more or leſs, and another Operation is to be made thus.

2d. With the Co-latitude newly aſſumed (either greater or leſs than that by the Reckoning) and the other things before mentioned, get the Elapſed Time in the ſame manner as before mentioned; and take the Difference between it and the Elapſed Time found by the Co-latitude of the Reckoning.

3d. When both of theſe Elapſed Times are found, it will plainly appear, which of the two Latitudes they have been computed from, is neareſt to the true Latitude, and whether both have been too great or to little. If one Elapſed Time be greater, and the other leſs than that meaſured by the Watch, the true Latitude is between the two Latitudes that have been uſed. Therefore, in this caſe,

4th. Subtract one computed Elapſed Time from the other, the Remainder is a firſt term in Direct Proportion; a ſecond term is the Difference of the two aſſumed Latitudes; and a third Term is the Difference between the meaſured Elapſed Time and either of the two computed ones; therefore, multiplying and dividing, the fourth term will be Miles or Minutes of Latitude, to be added to, or ſubtracted from, that Latitude which had it's correſpondent Difference compared with the true Elapſed Time meaſured by the Watch. In other words thus:

5th. As the Difference of the Elapſed Times computed from the aſſumed Latitudes; is to the Difference of thoſe Latitudes: ſo is the Difference between the true Elapſed Time and either of the computed Elapſed Times; to a number of Minutes, which added to or ſubtracted from the correſpondent aſſumed Latitude, as the caſe requires, gives the true Latitude required, when the Latitudes are aſſumed near enough for the truth.

Amongſt the Copper Plate Prints in the preſent Treatiſe are two for illuſtrating this Method of Computation; one being intitled, A Formula for Latitude, having aſſumed Latitudes and Elapſed Time, the other being a Calculation of an Example at large.

If the Learner be unacquainted with the Preparation for this Proceſs, he may obſerve as follows.

When the Altitude of the Sun's Lower Limb has been taken, his Semidiameter added thereto gives the Altitude of the Centre. The Mean Semidiameter is 16m. 3s; his Greateſt Semidiameter a little more than a Quarter of a Minute more than the mean, and his leaſt Semidiameter as much leſs than the Mean. The times of the year when the Sun's Semidiameter meaſures at a Medium, are near the beginning of April and 20th of September; the Greateſt Semidiameter the beginning of January, and Leaſt Semidiameter the beginning of July; from which it will be eaſy to judge what the

Semidiameter may be at other times of the year, within a few Seconds of a Degree.

The Rules for Polar diſtance and taking out the Logarithms, are as follows.

If the Declination and Latitude are alike, the Declination ſubtracted from 90 Degrees, but otherwiſe added to 90 Degrees gives the Polar-diſtance. The Logarithms, when Degrees are more than 90d. are taken for the Remainders to 180d. The Co. ar. is Log. coſecant with it's Index leſſened by 10.

The moſt eaſy and unexceptionable Rule for computing the Hour-angle, is thus.

Add together the Co-latitude, the Polar-diſtance and Co-altitude, and from their Half-ſum ſubtract the Co-altitude, to get a Remainder. Then add together the Co. ar. of the Colatitude, the Co. ar. of the Polar diſtance, the Sine of the Half-ſum, and Sine of the Remainder; Half the Sum of theſe four Logarithms being found in Sines; twice the correſpondent Coſine-Arch, is the Hour-angle from Noon ſought. If it be before Noon, the Sun is ſo much ſhort of Noon; but if it be after Noon, the Sun is ſo much paſt Noon, in Degrees and Minutes, and 15 Degrees is 1 Hour of Time.

SECTION III.

Of the *New* and *General Method*, whereby the Latitude is found, when two Altitudes and the Elapſed Time are given, and the Declination is nearly the ſame at both Obſervations.

New General Precepts.

1ſt. Add together, the Co-latitude by Account; the Polar-diſtance; and the Complement of the Leſſer Altitude; and from their Half ſum, ſubtract that Complement to get a Remainder.

2d. Add together, the Co. ar. of the Co-latitude; the Co. ar. of the Polar-diſtance; the Sine of the Half-ſum; and Sine of the Remainder; Half the Sum of theſe four Logarithms, is the Co-ſine of an Arch, which being doubled is *t*; and the Difference between *t* and the Degrees and Minutes of Elapſed-time, is *T*.

3d. Add together, the Sine of *T*, and Co-ſine of the Declination; omit Index 10. in the Sum; this is the Sine of *G*; whoſe Arch or Secant may be taken out by Inſpection.

4th. Add together, the Sine of the Declination, and Secant of *G*; omit Index 10. in the Sum; this is the Co-ſine of *A*.

5th. Add together, the Sine of the Greater Altitude, and Secant of *G*; omit Index 10. in the Sum; this is the Co-ſine of D.

6th. The Difference between *A* and the Co-declination, is *C* and *C* is to be added to *D* when the Polar-diſtance is leſs than 90°; but otherwiſe ſubtracted from it, to get *E* the Meridional Zenith-diſtance. The Sum or Difference of *E* and the Declination, as in uſual Caſes, is the Latitude corrected by the firſt Operation.

When the Latitude thus found is near that by Account, it needs no farther Correction; but when they differ much, a ſecond Operation with the corrected Latitude, is to be made as beſore.

The firſt Sight of this General Rule, diſcovers that it is derived from that beſore mentioned, wherein two Latitudes were aſſumed. In that Method, a Computation is made for both Altitudes and both Latitudes, and therefore there are four Proceſſes in each Operation.

In the Method here introduced, but one of thoſe four Proceſſes is retained; then follows a ſmall additional Part, and the Meridional Zenith-diſtance is had. In this additional Part, the Approximation is made with an erroneous Hour-angle, until the corrected Latitude is found.

Perſons who are able to judge of Mathematical Demonſtrations, may think that the Inveſtigation of ſuch a General Rule ſhould have gone with it. That is intended to be done in another Place, more compleatly than Room will well ſuit for it here. If ſuch had been here delivered, the Practice muſt have been ſuſpended, by the introduction of Theoretical Principles, and no one would have been the better able to put it into Execution.

The following, are Examples for illuſtrating this Method.

In theſe Examples, when the Zenith-diſtance is found; by applying thereto the Declination, the Latitude is found.

When you look North to take the Meridional Co-altitude, the Zenith-diſtance is North, and it is that Co-altitude. When you look South to take the Co-altitude, it is the Zenith-diſtance South.

1. When the Zenith-diſtance and Declination, are both North or both South; their Difference is the Latitude; and it is of the ſame name with the Declination, if the Declination is greater than the Zenith-diſtance; but otherwiſe the Latitude is of a name contrary to the Declination.

2. When the Zenith-diſtance and Declination are, one North and the other South; their Sum is the Latitude, and it is of the ſame name with the Declination.

In theſe two foregoing Rules; the Zenith-diſtance is ſuppoſed to be taken, when the Sun is above the Pole.

EXAMPLE

EXAMPLE I.

	° '
Latitude by Account.	51.29 N.
Sun's Declination	23.27 N.
Leſſer Altitude	45.26
Greater Altitude	50.20
Elapſed Time	8.48

OPERATION.

° '
38.31 =0.205692
66.33 =0.037438
44.34
149.38
74.49 =9.984569
30.15 =9.702236
19.929935
22.42½=9.964967
t = 45.25
Q = 8.48
T = 36.37 =9.775580
23.27 =9.962562
G = 33.10½=9.738142
23.27 =9.599827
= .077273
A = 61.36½=9.677100
50.20 =9.886362
= .077273
D = 23. 7 =9.963635
A = 61.36½
B = 66.33 Co-declination.
C = 4.56½
D = 23. 7
E = 28. 3½ Zenith-diſtance.
F = 23.27 Declination
51.30½ Latitude.

REMARKS.

In this Example, Six Figures of Logarithms beſide the Index are uſed; but it frequently happens that four Figures will be ſufficient; and when more are neceſſary, they commonly are wanted moſt in the two laſt Steps before the Logarithm of D. In ſuch caſes, the firſt Right-hand Figure in the Logarithm, muſt determine the neareſt Minute in the Tables.

EXAMPLE II.

	° '
Latitude by Account	51.32 N.
Sun's Declination	17.26 N.
Leſſer Altitude	47. 7
Greater Altitude	51.35
Elapſed Time	14.41

RESULTS.

By 1ſt. Operation.
° '
t = 37. 2
T = 22.21
G = 21.16½
A = 71.15
D = 32.46

A = 71.15
B = 72.34
C = 1. 9
D = 32.46
E = 34. 5
F = 17.26
Latitude 51.31

The Data of Example 1. are taken from a real Obſervation inſerted p. 14 of my Pamphlet on Elapſed Time 1778. The Data of this Example are from a real Obſervation by me Auguſt 3d. 1782. Both of theſe give the true Latitude without erring half a Mile. If the aſſumed Latitude had been wider from Truth a ſecond Operation would have been neceſſary.

REMARKS.

When double Altitudes are taken on Land by means of a Fluid Horizon, the Image of the Object is brought down on the ſmall Mirror, 'till it makes one with that reflected from the Artificial Horizon; then, half of the Degrees and Minutes on the Arch, is the Altitude of the Object, which is to be leſſened only by the Refraction.

When great exactneſs is required, the Errors ariſing from the Earth's Figure ſhould be corrected. Theſe Errors, are ſmalleſt near the Meridian and near the true Eaſt and Weſt points of the Horizon.

EXAMPLE III.

	° ′
Latitude by Account	46.20 *N.*
Sun's Declination	11.17 *N.*
Leaſt Altitude	46.55
Greateſt Altitude	54. 7
Elapſed Time	21.15

RESULTS.

By 1ſt. Operation.		By 2d. Operation.	
	° ′		° ′
t =	29.35	t =	29.24
T =	8.20	T =	8. 9
G =	8.10	G =	7.59½
A =	78.36	A =	78.36½
D =	35. 4	D =	35. 6
A =	78.36	A =	78.36½
B =	78.43	B =	78.43
C =	0. 7	C =	0. 6¾
D =	35. 4	D =	35. 6
E =	35.11	E =	35.12¾
F =	11.17	F =	11.17
Latitude	46.28	Latitude	46.29¾

Hence the true Latitude 46.30.

REMARKS.

In this Method of Approximation, the firſt thing found correct is the Latitude, after that, in the next Operation, *t* and *T* the Times from Noon, come out correct. Conſequently the Latitude and Solar Times of Obſervation, are correctly aſcertainable by the Data; and therefore, a Watch may be ſet to Solar Time, by this Method, at all times where the Sun's Altitudes and Elapſed Time can be meaſured. The Times and Circumſtances which limit the Application of the Natural Sines and Solar Tables, may be ſeen p. 21 and 22 New Tables and p. 75, 76 Old Table Elapſed Times.

EXAMPLE IV.

	° ′
Latitude by Account	51.30 *N.*
Sun's Declination	23.28 *N.*
Leaſt Altitude	37.30
Greateſt Altitude	62. 0
Elapſed Time	60. 0

RESULTS.

By 1ſt. Operation.		By 2d. Operation.	
	° ′		° ′
t	58.39	t	58.40
T	1.21	T	1.20
G	1.14	G	1.13½
A	66.31½	A	66.32½
D	27.58	D	27.58
A	66.31½	A	66.32½
B	66.32	B	66.32
C	0. 0½	C	0. 0½
D	27.58	D	27.58
E	27.58½	E	27.58½
F	23.28	F	23.28
Lat.	51.26½	Latitude	51.26½

REMARKS.

When the reſulting Numbers beginning at *t*, do begin to come out either the ſame or nearly alike, no further Operation need be made, becauſe the Latitude before found is the true Latitude. Nevertheleſs, if great Exactneſs is required, it may be continued even to Seconds of a degree, but in ſuch Caſes it will be neceſſary either to make uſe of Tables which give the Logarithms to Seconds, or to proportion them, ſo that there be no Error by neglecting the overplus which is not ſhewn by the Tables.

EXAMPLE V.

	° ′
Latitude by Account	5. 0 *N.*
Sun's Declination	2. 0 *N.*
Leaſt Altitude	16. 0
Greateſt Altitude	86. 0
Elapſed Time	75. 0

RESULTS.

By 1ſt. Operation.		By 2d. Operation.	
	° ′		° ′
t	74. 7	*t*	74. 7
T	0.53	*T*	0.53
G	0.53		
A	88. 0		
D	3.54		
A	88. 0		
B	88. 0		
C	0. 0		
D	3.54		
E	3.54		
F	2. 0		
Lat.	5.54		

REMARKS.

In this Example, the Values of *t* and *T* come out the ſame in the ſecond Operation as in the firſt; therefore, theſe are the correct Solar Times from Noon in Degrees, and the Latitude is correctly found by the firſt Operation.

In this Method of Computation, no allowance is made for the Change of the Sun's Declination between the Obſervations; this at 2° of Declination will amount to near 5′ in the 5 Hours of Elapſed Time given. The Effect this will produce, or any other greater Change, is eaſily provided for in the Formula for that purpoſe farther on.

It may be here obſerved, that the Method by Natural Sines and Solar tables, is wholy deficient in this particular; and therefore cannot be truly applied at many times when the Latitude is wanted.

It may be farther noted that, in this Queſtion, one of the Altitudes is two Hours more remote from the Meridian, than that Method can anſwer.

EXAMPLE VI.

	° ′
Latitude by Account	4. 0 *N.*
Sun's Declination	7. 0 *N.*
Leſſer Altitude	16. 0
Greater Altitude	82. 0
Elapſed Time	75. 0

RESULTS.

By 1ſt. Operation.		By 2d. Operation.	
	° ′		° ′
t	74.21	*t*	73.45
T	0.39	*T*	1.15
G	0.39	*G*	1.14
A	83. 0	*A*	83. 0
D	7.58	*D*	7.54
A	83. 0	*A*	83. 0
B	83. 0	*B*	83. 0
C	0. 0	*C*	0. 0
D	7.58	*D*	7.54
E	7.58	*E*	7.54
F	7. 0	*F*	7. 0
Lat.	0.58S	Lat.	0.54S

REMARKS.

When the Sun's Declination exceeds the Latitude of the place; if any difficulty ariſes in determining whether the Latitude is North or South, the beſt way is to make a ſmall Diagram for obviating the Difficulty. After this if any Uncertainty remains; work with the true Co-latitude, the Polar-diſtance and Complement of the Greateſt Altitude, as is done with the ſame Co-latitude Polar-diſtance and Complement of the Leſſer Altitude; and thus *t* and *T* being found, their Sum or difference, as the caſe will ſhew, is the Elapſed Time, and proof of the Latitude thus found being the true Latitude required.

EXAMPLE VII.

	° '
Latitude by Account	3. 0 *N.*
Sun's Declination	6. 0 *N.*
Leſſer Altitude	18. 0
Greater Altitude	86. 0
Elapſed Time	70. 0

RESULTS.

By 1ſt. Operation.		By 2d. Operation.	
	° '		° '
t	72.14	*t*	72.10
T	2.14	*T*	2.10
G	2.13	*G*	2. 9
A	84. 0	*A*	84. 0
D	3.20	*D*	3.23
A	84. 0	*A*	84. 0
B	84. 0	*B*	84. 0
C	0. 0	*C*	0. 0
D	3.20	*D*	3.23
E	3.20	*E*	3.23
F	6. 0	*F*	6. 0
Lat.	2.40	Lat.	2.37

REMARKS.

When the Latitude has been aſſumed ſomewhat near the Truth in the firſt Operation, it is obſerveable, that the values of *A* in all ſucceeding Operations will come out nearly the ſame. This ſuggeſts a Contraction in ſuch caſes; for, if the value of *A* is once well aſcertained, the value of *G* may be again found and that *A* may be applied to find *D*, to ſhorten the work.

When the firſt Operation is made, particular regard ſhould be had, to the Quantity of the Correction made, becauſe this indicates the Quickneſs with which the ſolution approaches the Truth. In many Caſes, this will render a ſecond Operation unneceſſary for practical Uſes.

EXAMPLE VIII.

	° '
Latitude by Account	43.30 *N.*
Sun's Declination	23.28 S.
Leſſer Altitude	10. 0
Greater Altitude	22. 0
Elapſed Time	45. 0

RESULTS.

By 1ſt. Operation.		By 2d. Operation.	
	° '		° '
t	47.42	*t*	46.16
T	2.42	*T*	1.16
G	2.29	*G*	1.10
A	66.30½	*A*	66.31½
D	67.58	*D*	67.59½
A	66.30½	*A*	66.31½
B	66.32	*B*	66.32
C	0. 1½	*C*	0. 0½
D	67.58	*D*	67.59½
E	67.56½	*E*	67.59
F	23.28	*F*	23.28
Lat.	44.28½	Lat.	44.31

REMARKS.

Although in moſt Caſes, two Operations will be ſufficient to determine the true Latitude, there may be ſome in which the Data have ſuch Relation to each other, that a farther Proceſs may be neceſſary. When ever there is reaſon to ſuſpect this may be the Caſe; after two Operations are made, ſtrict regard ſhould be had to the manner in which a Convergency has been toward the Truth. If this has been, through the whole either Increaſing or Decreaſing, or partly of both; the order of the Differences will ſhew nearly what is to be allowed, almoſt by Inſpection.

EXAMPLE. IX.

	° '
Latitude by Account	50.40 *N.*
Sun's Declination	20. 0 *S.*
Leſſer Altitude	17.13
Greater Altitude	19.41
Elapſed Time	15. 0

RESULTS.

By 1ſt. Operation.	° '	By 2d. Operation.	° '
t	19.48	*t*	21.48
T	4.48	*T*	6.48
G	4.30	*G*	6.23
A	69.56	*A*	69.52
D	70.15½	*D*	70.11½
A	69.56	*A*	69.52
B	70. 0	*B*	70. 0
C	0. 4	*C*	0. 8
D	70.15½	*D*	70.11½
E	70.11½	*E*	70. 3½
F	20. 0	*F*	20. 0
Lat.	50.11½	Latitude	50. 3½

REMARKS.

In this Queſtion the Complement of the Greateſt Altitude added to the given Co-latitude, makes leſs than the Polar diſtance and therefore the given Data are impoſſible; nevertheleſs, the Operations converge toward the Truth. When ſuch a Convergency ſeems to be ſlow, the Correction after the 2d. Operation may be had thus.

Lat. 50°.40' decreaſes 28½' to Lat. 50°.11½'
Lat. 50.11½ decreaſes 8 to Lat. 50. 3½
Therefore,
Lat. 50. 3½ decreaſes 2¼ to Lat. 50. 1¼
Lat. 50. 1¼ decreaſes 0¾ to Lat. 50. 0½
Hence 50. 0½ is the true Latitude.

When the Data are given in Degrees, Minutes and Seconds; for Geographical Purpoſes, this Method of Approximation will be not only eaſy, but anſwer to the greateſt Accuracy.

EXAMPLE X.

	° '
Latitude by Account	49.10 *N.*
Sun's Declination	20. 0 *S.*
Leſſer Altitude	17.13
Greater Altitude	19.41
Elapſed Time	15. 0

RESULTS.

By 1ſt. Operarion.	° '	By 2d. Operation.	° '
t	25.30	*t*	23.40
T	10.30	*T*	8.40
G	9.52	*G*	8. 8½
A	69.41	*A*	69.47
D	70. 1	*D*	70. 6
A	69.41	*A*	69.47
B	70. 0	*B*	70. 0
C	0.19	*C*	0.13
D	70. 1	*D*	70. 6
E	69.42	*E*	69.53
F	20. 0	*F*	20. 0
Lat.	49.42	Latitude	49.53

REMARKS.

Lat. 49°.10' increaſes 32' to Lat. 49°.42'
Lat. 49.42 increaſes 11 to Lat. 49.53
Lat, 49.53 increaſes 5 to Lat. 49.58
Lat. 49.58 increaſes 2¼ to Lat. 50. 0¼
Lat. 50. 0¼ increaſes 1 to Lat. 50. 1¼
Lat. 50. 1¼ increaſes ½ to Lat. 50. 1¾
Lat. 50. 1¾ increaſes to the true Lat. 50. 2

From the two foregoing Examples, it appears that ſometimes the Approximation will be by a continued decreaſe and at other times by a continued increaſe, until the true Latitude is found; and therefore two Operations, will be all that are wanted in uſual Caſes.

By the following, it appears that ſometimes the Approach will be by alternate ſteps, and the Truth is nearly between the Extreams.

EXAMPLE XI.

	° ′
Latitude by Account	47.24 *N.*
Sun's Declination	12.20 *N.*
Leſſer Altitude	49.18
Greater Altitude	52. 4
Elapſed Time	42.30

RESULTS.

By 1ſt. Operation.		By 2d. Operation.	
	° ′		° ′
t	24.41	*t*	25. 3
T	17.49	*T*	17.27
G	17.23½	*G*	17. 2
A	77. 3½	*A*	77. 5½
D	34.15½	*D*	34.25
A	77. 3½	*A*	77. 5½
B	77.40	*B*	77.40
C	0.36½	*C*	0.34½
D	34.15½.	*D*	34.25
E	34.52	*E*	34.59½
F	12.20	*F*	12.20
Lat.	47.12	Latitude	47.19½

REMARKS.

In Operations like the above, where the Latitude decreaſes and increaſes, or increaſes and decreaſes alternatively, the true Latitude will be nearly a Medium between the two Extreams. Thus in the above, the Medium of the firſt and ſecond is 47°. 18′ the Medium of ſecond and third is 47°. 15′¾ and the 47°. 15′¾, and the medium of theſe two is 47°. 16¾, which is near the Truth.

Otherwiſe, having made the ſecond Operation, the Effects of other Operations may be had by proportioning the Differences, thus; ſetting down the parts of a Minute in Tenths.

	° ′		′			° ′
Lat.	47.24	dec.	12,0	to	Lat.	47.12
Lat.	47.12	inc.	7,5	to	Lat.	47.19,5
Lat.	47.19,5	dec.	4,7	to	Lat.	47.14,8
Lat.	47.14,8	inc.	3.0	to	Lat.	47.17,8
Lat.	47.17,8	dec.	1.9	to	Lat.	47.15,9
Lat.	47.15,9	inc.	1,2	to	Lat.	47.17,1

The Medium of the latter two, when a near Approach is made to the Truth, gives the Latitude, 47.16½.

EXAMPLE XII.

	° ′
Latitude by Account	49.17 *N.*
Sun's Declination	23.28 *S.*
Leſſer Altitude	12.49
Greater Altitude	14.15
Elapſed Time	55. 0

RESULTS.

By 1ſt. Operation.		By 2d. Operation.	
	° ′		° ′
t	28.54	*t*	30.57
T	26. 6	*T*	24, 3
G	23.48	*G*	21.57
A	64 12	*A*	64.34½
D	74.23½	*D*	74.36½
A	64.12	*A*	64.34½
B	66.32	*B*	66.32
C	2.20	*C*	1.57
D	74.23½	*D*	74.36½
E	74. 3½	*E*	72.39
F	23.28	*F*	22.28
Lat.	48.35½	Latitude	49.11

REMARKS.

Here, the Latitude corrected decreaſes and increaſes alternately, the Medium of the firſt and ſecond is 48°.56′¼, and of the ſecond and third is 48°.53′¼, and the Medium of theſe two is 48°.54′¾ the Latitude required.

Otherwiſe, by proportioning the Differences

° ′	° ′	° ′
Lat.49.17	dec.toLat.48.35,5	mean48.56,25
Lat.48.35,5	inc.toLat.49.11	mean48.53,26
Lat.49.11	dec.toLat.48.41,5	mean48.56,25
Lat.48.41,5	inc.toLat.49. 5	mean48.53,25
Lat.49. 5	dec.toLat.48.46	mean48.55,5
Lat.48,46	inc.toLat.49. 2,5	mean48.54,25

Med. of all the Means48,54,8 or 48,55.

Otherwiſe, a Medium might have been taken of any two of the above extreams, and it would have come near enough the Truth for Uſe at Sea. I might here proceed farther; but, theſe are Improvements not to be found in the Solar Tables, nor any Comments on them.

Here might be introduced Solutions to other Queſtions to illuſtrate and confirm the Truth of this Method. For

EXAMPLE XIII.

If that p. 68 of Elapſed Time 1769 be prepared and ſolved by this Method; there will be the

		° ′
given Co-lat. *N.*		30. 0
	Polar-diſtance	90. 0
	Co. leaſt Alt.	69.18
	Elapſed Time	30. 0

	° ′		° ′
t	45. 0	*A*	90. 0
T	15. 0	*B*	90. 0
G	15. 0	*C*	0. 0
A	90. 0	*D*	60. 0
D	60. 0	*E*	60. 0
		F	0. 0
		Lat.	60. 0

EXAMPLE XIV.

If that p. 73 of the laſt mentioned be ſolved by this Method, there will be the

given Co. lat. *N.*		42.10
	Polar-diſtance	103.17
	Co. leaſt Alt.	73.11
	Elapſed Time	52.30

By 1ſt. Operation		By 2d. Operation	
	° ′		° ′
t	45.16	*t*	44.48
T	7.14	*T*	7.42
G	7. 2	*G*	7.29½
A	76,37	*A*	76.36
D	61.34	*D*	61.32
C	0. 6	*C*	0. 7
E	61.28	*E*	61.25
F	13.17	*F*	13.17
Lat.	48.11	Lat.	48. 8

Hence the true Latitude 48. 7½

EXAMPLE XV.

If that p. 65. of the forementioned be ſolved by this Method, there will be the

given Co. lat. *N.*		42.41
	Polar-diſtance	77.44
	Co. leaſt Alt.	40.51
	Elapſed Time	42.30

By 1ſt. Operation.		By 2d. Operation.	
	° ′		° ′
t	25. 2	*t*	24.58
T	17.28	*T*	17.32
G	17. 3½	*G*	17. 7½
A	77. 9½	*A*	77. 9½
D	34.30½	*D*	34.28½
C	0.34½	*C*	0.34½
D	34.30½	*D*	34.28½
E	35. 5	*E*	35. 3
F	12.16	*F*	12.16
Lat.	47.21	Lat.	47.19

This Queſtion is under the increaſing and decreaſing Circumſtances; therefore the Medium is the true Latitude 47.20

EXAMPLE XVI.

If that P. 67 be ſolved thus, there will be given

Co-lat. *N.*		39.20
	Polar diſtance	110. 0
	Co. leaſt Alt.	72.47
	Elapſed Time	15. 0

By 1ſt. Operation.		By 2d. Operation.	
	° ′		° ′
t	19.57	*t*	21.48
T	4.57	*T*	6.48
G	4.39	*G*	6.23
A	69.56	*A*	69.52½
D	70.15	*D*	70.11
A	69.56	*A*	69.52½
B	70. 0	*B*	70. 0
C	0. 4	*C*	0. 7½
D	70.15	*D*	70.11
E	70.11	*E*	70. 3½
F	20. 0	*F*	20. 0
Lat.	50.11	Lat.	50. 3½

and then by Inſpection to Lat. 50. 1

EXAMPLE XVII.

If that p. 70. of the forementioned be ſolved by this Method, there will be, the

given Co-lat. *N.*		42.26
	Polar-diſtance	109.30
	Co. leaſt Alt.	72.20
	Elapſed Time	44.40

By 1ſt. Operation		By 2d. Operation.	
	° ′		° ′
t	30.11	*t*	30.51
T	14.29	*T*	19.49
G	13.38	*G*	13. 1
A	69.54	*A*	69.58
D	67.24½	*D*	67.28½
Lat.	47.18½	Lat.	47.26½

This Queſtion is under the Decreaſing and Increaſing, Circumſtances, and as ſuch decreaſes 15′, increaſes 8′, decreaſes 4, increaſes 2′, decreaſes 1′, increaſes ½′; hence, the true Latitude is 47.24

EXAMPLE XVIII.

If that p. 74. Britiſh Mariner's Guide be taken; there will be, the

given Co. lat. *N.*		41.30
	Polar-diſtance	109.34
	Co-leaſt Alt.	76.10
	Elapſed Time	23. 1

By 1ſt. Operation,		By 2d. Operation.	
	° ′		° ′
t	38.18	*t*	37.51
T	15.17	*T*	14.56
G	14.23	*G*	14. 3½
A	69.46½	*A*	69.48½
D	68.54½	*D*	68.56½
C	0.39½	*C*	0.37½
D	68.54½	*D*	68.56½
E	68.15	*E*	68.19
F	19.34	*F*	19.34
Lat.	48.41	Lat.	48.45

Hence, the true Latitude 48.43

SECTION IV.

Of the *Charts* of *Zodiacal Stars*, the firſt and ſecond Forms.

The Uſe of theſe Charts is on the Plates themſelves. In finding the Latitude by Altitudes of two Stars, they ſhew which of them is Eaſt or Weſt of the other; and by directions farther on, which is neareſt to the Meridian. They diſtinguiſh the Zodiacal Stars from others, in the Lunar Method of finding the Longitude at Sea, when the Places of the Sun and Moon are found in the Zodiac for a given Day; for then their Poſitions to each other and the Stars, appear in Miniature on theſe Charts, as they may be ſeen in the Heavens.

SECTION V.

Of the two Tables of *Equation* of *Time*.

One of theſe Tables is for Even Days, the other for Odd Days, and therefore, both ſhew the Equation for every Day in the Year. In theſe Tables, it is ſhewn what a Watch or Clock that keeps Mean Solar Time ſhould ſtand at, when the Sun is on the Meridian; this Method is well adapted for ſetting a Clock or Watch by the Sun's Meridional Tranſit on Land, and not liable to Difficulty, in ſhewing whether the Sun or a Time-keeper ſhould be ſooneſt or lateſt, at Sea. In theſe Tables, every fourth Year, the Numbers return nearly the ſame; therefore, they will continue good, a great length of Time

SECTION VI.

Of the *Compaſs Card* and its *Points*.

In the Compaſs Card, Diviſions and Sub-diviſions of its Points; the Quadrant of 90 Degrees is divided into Eight equal parts for Points; after that each Point is divided in a different manner by different Perſons; but I here recommend, that each Point be divided into Eight equal parts, and each of theſe Eighths into Eight other Sub-diviſions.

In the Table, the Degrees and Minutes to every Eighth part of a Point are ſhewn by Inſpection. For greater accuracy, obſerve the following Directions.

1st. To turn Points and Sub-diviſions, into Degrees and Minutes.

To the Eighths of Half-quarter Points, add a Cypher, and they are Eightieths; then for every 20 contained in theſe Eightieths, add to them a Minute, and the Sum is the Minutes of a Degree in the Eighths of Half-quarter Points; add theſe to the Degrees and Minutes in the table, anſwering to the next leſs Points and Eighths, and the Sum ſhews the Degrees and Minutes of the whole.

2d. To turn Degrees and Minutes into Points and Sub-diviſions.

Take out the Points and Eighths, and their Degrees and Minutes in the Table, which are next leſs than the Degrees and Minutes given. Subtract thoſe Degrees and Minutes from each other, and for every 20 Minutes in the Remainder, leſſen it by a Minute, this gives the Eightieths of a Half-quarter Point, and the neareſt left hand Figure ſhews the Eighths of a Half-quarter Point.

That the two foregoing Rules will be of Uſe in Navigation is evident. The Ships Courſe is commonly eſtimated by Points and Sub-diviſions, but the Variation is obſerved and computed by Amplitude and Azimuth in Degrees and Minutes; and one is to be either added to or ſubtracted from the other to get the true Courſe.

1ſt. Suppoſe for Inſtance, a Ship is ſailing by Compaſs 3 Points, 5 Eighths and 2 Eighths of a Half-quarter Point; it is by almoſt Inſpection 40° 47′ and 21′, or 41° 8′. And the Variation added or ſubtracted, gives the true Courſe.

2d. If a Ship's true Courſe be 41° 8′, it is 3 Points 5 Eighths by Inſpection, and for the remaining 21′, there are 2 Eighths of a Half-quarter Point.

To be ſtrictly correct, the above Number 20 ſhould be 21, but the former may not tend to puzzle ſo much as the latter; and in uſual Caſes, this Method eaſily reduceth to the neareſt Minute of a Degree.

SECTION VII.

Of the *Right Aſcenſions* and *Declinations* of *Fixed Stars*.

This Table contains not only the larger Stars uſed in the Lunar Method of finding the Longitude, but thoſe which are the moſt proper for the Latitude, either on the Meridian or remote therefrom.

The Right Aſcenſions are in Degrees and Minutes, becauſe this Method of expreſſing them is more convenient than by Time.

In practiſing for Latitude and Longitude by the Methods in this Work, the Obſerver will compare thoſe Right Aſcenſions with the Sun's in Degrees and Minutes; but the Nautical Ephemeris, only ſhews the Sun's Right Aſcenſion in Time.

At the bottom of this Table, is a Miniature ſketch of the Equator and Ecliptic, as they are at large in the Chart of Zodiacal Stars. This Delineation may aſſiſt the Judgement in many Caſes when the Chart of Stars is not at hand, concerning the ſituation of the Sun, Moon, Stars, Equinoctial Points Aries and Libra, and that Point of the Equator or Ecliptic on the Meridian, in order to know, the Poſitions of the Circles of the Sphere.

SECTION VIII.

Of the Table of *Refraction* in *Altitude*.

The Refraction in this Table, is to be ſubtracted from the obſerved Altitude; but when the Altitude is between any two in the Table, a Proportionable Part of Refraction is to be found, either additive or ſubductive to get the Refraction required.

This Table is applicable, both in finding the Latitude; and Longitude at Sea, when the Computation is made by the Common Logarithmic Tables.

SECTION IX. Formula I.

Of the Formula for Latitude, having aſſumed Latitude and Elapſed Time; and the Calculation at large following it.

The Uſe of this Formula, and the manner of applying it hath been fully explained in Section II. The Calculation, is a Specimen of the work.

In one Operation by this Method, the Calculation is much like that for an Azimuth by the common Method.

In one Operation by this Method, the Logarithmic Tables, are turned to Sixteen times; and Eight of theſe are under ſuch Circumſtances, that one four of the Eight are turned to, near the ſame Pages, where the other four of the Eight are turned to; this takes off part of the Time that would be employed in turning to ſeparate Places.

This Method is general; and therefore, not limited to particular Caſes or Time.

The Delineation at the Top of the Calculation at large, is an Orthographical Delineation on the Plane of the Meridian, ſhewing the Errors to be corrected by the Calculation.

SECTION X. Formula II.

Of the New Formula for Latitude having Sights of the Sun, Elapſed Time, and Equal Declination.

This Formula is derived from the Principles on which the foregoing Formula is founded, and a Compoſition and Reſolution of certain peculiar Properties of the Sphere.

As this Formula is for Equal Declination; if there be any Change of it during the Elapſed Time, the Mean Declination ſhould be uſed.

The greateſt Altitude ſhould be taken as correct as poſſible, and the nearer the Meridian, the better. The Number of figures to be uſed ſhould be ſuch, that no Uncertainty may ariſe concerning the neareſt Minute, in finding Number *D*.

In working by this Formula, the Logarithms are turned to Eleven times in different Pages, this is but once more than in uſing the Solar Tables; the other parts of the Proceſs are eaſy and come out to the neareſt Half-minute by Inſpection without Proportional Parts. Beſides.

This Formula is general, unlimitted to Time and Caſes.

The Blank Space is for continuing the Computation to the Hour-angle and Azimuth, when the Latitude is found.

SECTION XI. Formula III.

Of the New Formula for Latitude, having Sights of the Sun with Elapſed Time.

This Formula, hath almoſt all the Properties of the foregoing; beſides, here is an ample proviſion for the Change of Declination in the Interval of Elapſed Time; whereas, in the former, there is none.

By this, the greateſt Exactneſs may be attained, when the Obſervations have been well made, and there hath been due allowance for the Change of the Ship's Place in the Interval of Elapſed Time.

SECTION XII. Formula IV.

Of the New Formula for Latitude, having Sights of Stars.

In the former Sections, it hath been ſhewn, that there is no Allowance for Change of Declination in the Elapſed Time, when the Logarithmic Solar Tables and Natural ſines are uſed; but that ſuch Allowance is made and the true Latitude found, in my Method by two aſſumed Latitudes with the Elapſed Time; and by the Formula in the former Section.

Whilſt the Solar Tables will ever be confined to an Equal Declinations, critical Circumſtances and contracted Times, beyond which their beſt Commentators have not allowed them to be ſerviceable; both of theſe laſt mentioned Methods, extend to the Solution of a Variety of other Problems of the Sphere, which are eaſily to be practiſed, and of great Uſe in Navigation. For,

When the Altitudes of two Fixed Stars are taken, their Declinations and Equatorial-diſtance being known; there will be the ſame Data, as when two Altitudes of the Sun, with different Declination at the times of Obſervation, and the Elapſed Time are given. Conſequently my Method of applying, the Latitude by Account, a Watch for the Elapſed Time, the two Altitudes, and two Declinations; applieth in the ſame manner, the Latitude by Account, the Equatorial-diſtance of the two Stars, their two Altitudes, and two Declinations; and thereby determines the true Latitude.

The true Latitude being thus found, the Solar Time at each Obſervation is known by comparing the Right Aſcenſion of either of the two Stars, with the Right Aſcenſion of the Sun.

SECTION

SECTION XIII. Formula V.

Of the New Formula for Latitude, having Sights of Sun and Moon.

In the Uſe of this Formula, it is neceſſary to know ſomewhat near the truth what Hour it is at Greenwhich when the Obſervation is made at the Ship; this may be correct enough in uſual caſes, by adding 32 Minutes to the obſerved Diſtance of the Limbs to get the Rough Central Diſtance, with which, amongſt the Three-hourly Diſtances, the neareſt Hour for Greenwich is ſhewn by Inſpection.

If the Moon's Declination changes ſlowly at the Time of Obſervation no greater Accuracy than the foregoing is wanted; but if that Declination changes much in 12 Hours, the true Diſtance of Centres ſhould be found as in computing the Longitude, and then the Time of the Obſervation at Greenwich.

Having the Time at Greenwich the Sun and Moon's Right Aſcenſions and Declinations are taken from the Ephemeris, and thence their Equatorial-diſtance. Likewiſe, the obſerved Altitudes are reduced to the true Altitudes by Directions in the Formula, and then the Data become prepared for a Solution, in the ſame manner as the Data when two Stars are obſerved.

When the true Latitude is found, if the Sun is fartheſt from the Meridian his Equatorial-diſtance from Noon is found, by the Co-latitude, the Sun's Polar-diſtance and his Co-altitude: but, when the Moon is fartheſt from the Meridian, her Equatorial-diſtance from the Meridian is found, by the Co-latitude, the Moon's Polar-diſtance and her Co-altitude; and then, by their Equatorial Diſtance, the Sun's Diſtance from the Meridian is found, however near to that Meridian. The Sun's Equatorial-diſtance from the Meridian, is the Solar Time either ſhort of Noon or paſt Noon.

SECTION XIV.

Of the Longitude Inſtructions, and Supplementary Longitude Inſtructions.

The firſt of theſe contains General Directions for computing the Longitude, having the Latitude of the Place and the three cotemporary Obſervations. The latter contains Directions for preparing the Numbers, ſhortening the Proceſs and avoiding Error.

The Requiſite Tables peculiar to theſe Inſtructions, are in the firſt Edition, and the Tables for Refraction and Parallax, as they were there left by Mr. Lyons himſelf.

In thoſe Tables he names the firſt Column of his fourth Table "Parallax in Altitude or Diſtance" whilſt it is only Parallax in Altitude. In his Directions, what is to be done with his firſt and ſecond Arcs, I found the greateſt Difficulty, in conveying his meaning to others. Theſe and many other greater ones are thrown off in my firſt and latter Formulas; and they are my own Improvements.

SECTION XV. Formula VI.

Of the New and Eaſy Formula for the Longitude, by Sun and Moon.

The Directions for Computing by this Formula, are at large in the Longitude Inſtructions and the Supplementary ones.

It is become cuſtomary of late to ſet a Watch to Time at Sea and let it ſhew the Time at the Ship, or rather the Meridian the Ship was under when the Watch was ſet. I have no Objection to this Method, provided there is no Error in the ſetting of the Watch, or its going, or the eſtimated Courſe and Diſtance after the Watch is ſet; but, all theſe ſeem to be precarious, and the whole is a Quadruple Method of finding the Longitude at Sea.

The Truth of the Lunar Method depends wholly on its own Inſtruments, Ephemeris and Requiſite Tables.

SECTION XVI. Formula VII.

Of the Formula for Longitude, having the Ephemeris and and Common Tables of Logarithms.

The ſame Directions that were given for working by the former Formula, are to be uſed in this; except were Mr. Lyons's Tables or the Proportional Logarithms are applied. Inſtead of theſe, the Common Logarithms and beſt Tables of Refraction are here uſed, as directed in the Formula itſelf.

SECTION XVII. Formula VIII.

Of the Formula for Latitude, Time and Azimuth; having Sights of the Sun and Elapſed Time.

As it is cuſtomary for Ships at Sea, to have their Latitude by Account not a great number of miles erroneous, whenever that my be judged to be the Caſe, this Formula may be fully applied. In other Caſes, a previous Approximation is to be made toward the true Latitude, and then it may be applied.

The firſt thing to be found by this Formula, is the true Latitude, whether the Declination be equal or changeable; next, the two Times from Noon; and laſt, either or both of the Azimuths.

The Times will adjuſt a Watch and make it fit to carry Time till Night; to ſhew Time at the Ship, when Longitude is taken by Moon and Stars. The computed Azimuth compared with the obſerved Azimuth, gives the Variation.

The Hour-angle being found, the Azimuth-angle might be found by a ſingle Proportion in Sines; but that will be often attended with Ambiguity and conceal the Anſwer. No Ambiguity can happen, if the Method be uſed which is in the Formula.

SECTION XVIII. Formula IX.

Of the Formula for Latitude and Longitude, having Sights of Sun and Moon, or Moon and Stars.

In the Uſe of this Formula, there are given the Latitude by Account and the three Cotemporary Obſervations, and no more, in Order to determine both the Latitude and Longitude.

The firſt Column of the Formula, ſhews the Order how the true Latitude and Time at the Ship are to be approximated, whether it be a Day or Night Obſervation. In this Part, when the Moon is in the Queſtion, her Parallax muſt be cleared as in Section XIII; and if a Star is concerned, its Right Aſcenſion muſt be applied, to get the Time at the Ship.

The Second Column, works the true Diſtance of Centers; and the third Column the Time at Greenwich. If the Time at the Ship is truly found by the firſt Column, there is no need to work for it as in the third Column.

The Sum or Difference of the two Times is the Longitude from Greenwich.

SECTION XIX. Formula X.

Of the New and Eaſy Formula for Longitude and Latitude, having Sights only.

In the Uſe of this Formula, the ſame things are given and required, as in the foregoing Formula; but here, the Time at Greenwich is firſt found, and then the Latitude and Time at the Ship, to get how much they differ from each other, for the Longitude.

SECTION XX.

Directions for finding the true Meridian in the Night, when the Stars appear, in North Latitude.

Firſt. Find the four Stars α, β, γ, δ, in the Square of the Great Bear. Of theſe α and δ are neareſt to the Pole Star; and β and γ fartheſt from the Pole Star.

Secondly. Imaginarily divide the Diſtance from α to δ into Eight equal Parts, and the Diſtance from β to γ into Four equal Parts, and on thoſe two Lines take from α to δ one Eighth of its Diſtance; and from β to γ one Fourth of its Diſtance, to come to the Pole Star's Meridian, on the oppoſite Side of the Pole.

Thirdly. Direct your Sight from the Pole Star toward thoſe Points in its Meridian, and at the Diſtance of near Two Degrees from the Pole Star in that Line, is the true Pole.

Fourthly. An Horizontal Line paſſing South and North to the Point under the true Pole, is the Terreſtrial Meridian.

By this Method, it may be known what Stars are far Eaſt or Weſt of the Meridian, and what are nearly over it, at all Places in North Latitude; and the ſame Method may be uſed, with Proper Stars not too far from the South Pole. S. DUNN.

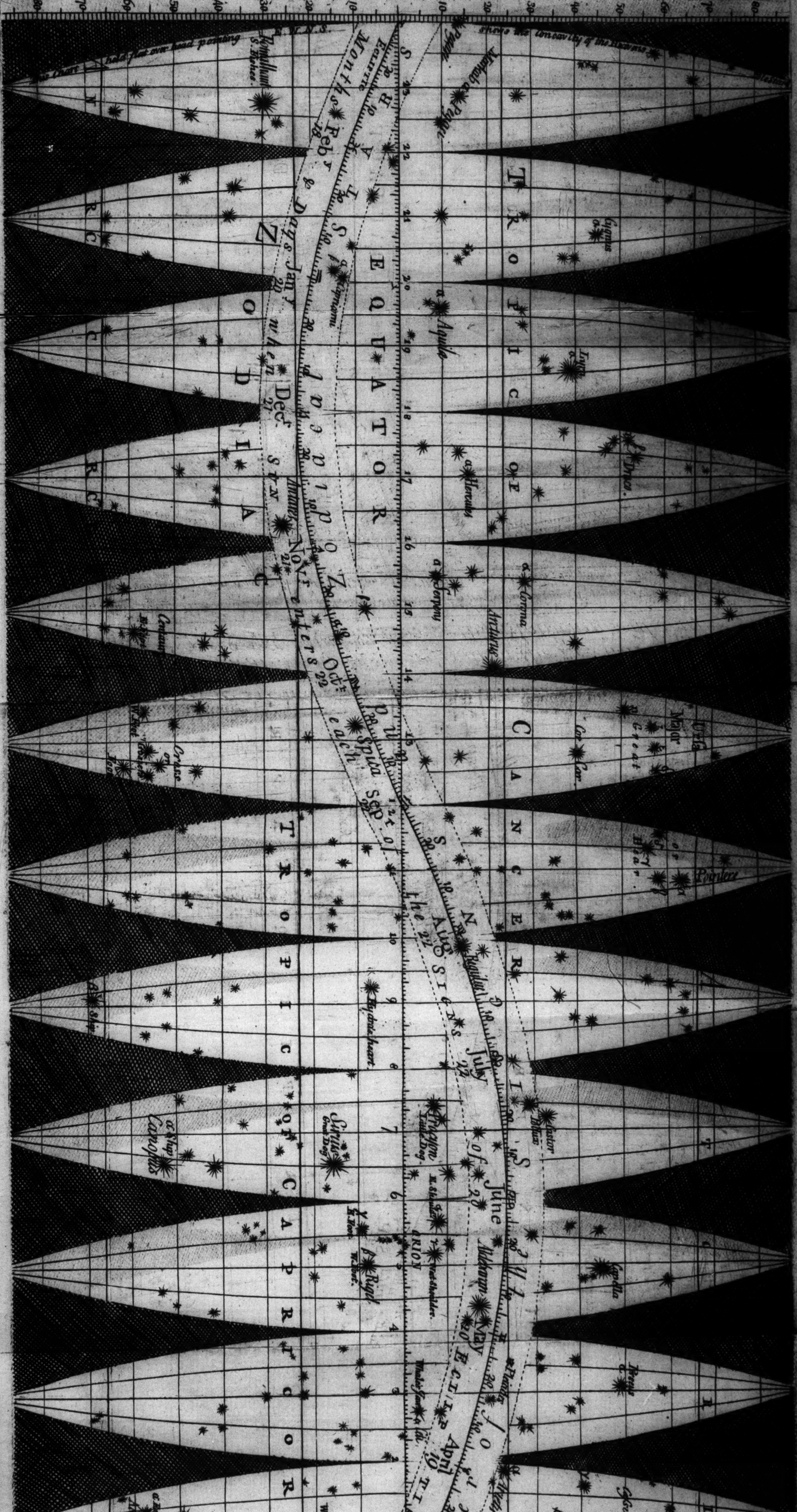
The End.

London Sept. 4th, 1782.

A CHART of the Zodiacal Stars Used in Finding the LONGITUDE at SEA the 1st Form; By S. DUNN, Teacher of the Mathematical Sciences.

Find the Sun, Moon & Planets Places in the Zodiac, by an Ephemeris, & their Positions to the Zodiacal Stars will appear by Inspection. For Hours of a Day past Noon, count to the Left; for before Noon to the Right of the Sun, gives the Stars on the Meridian; For farther see Treatise Longitude at Sea.

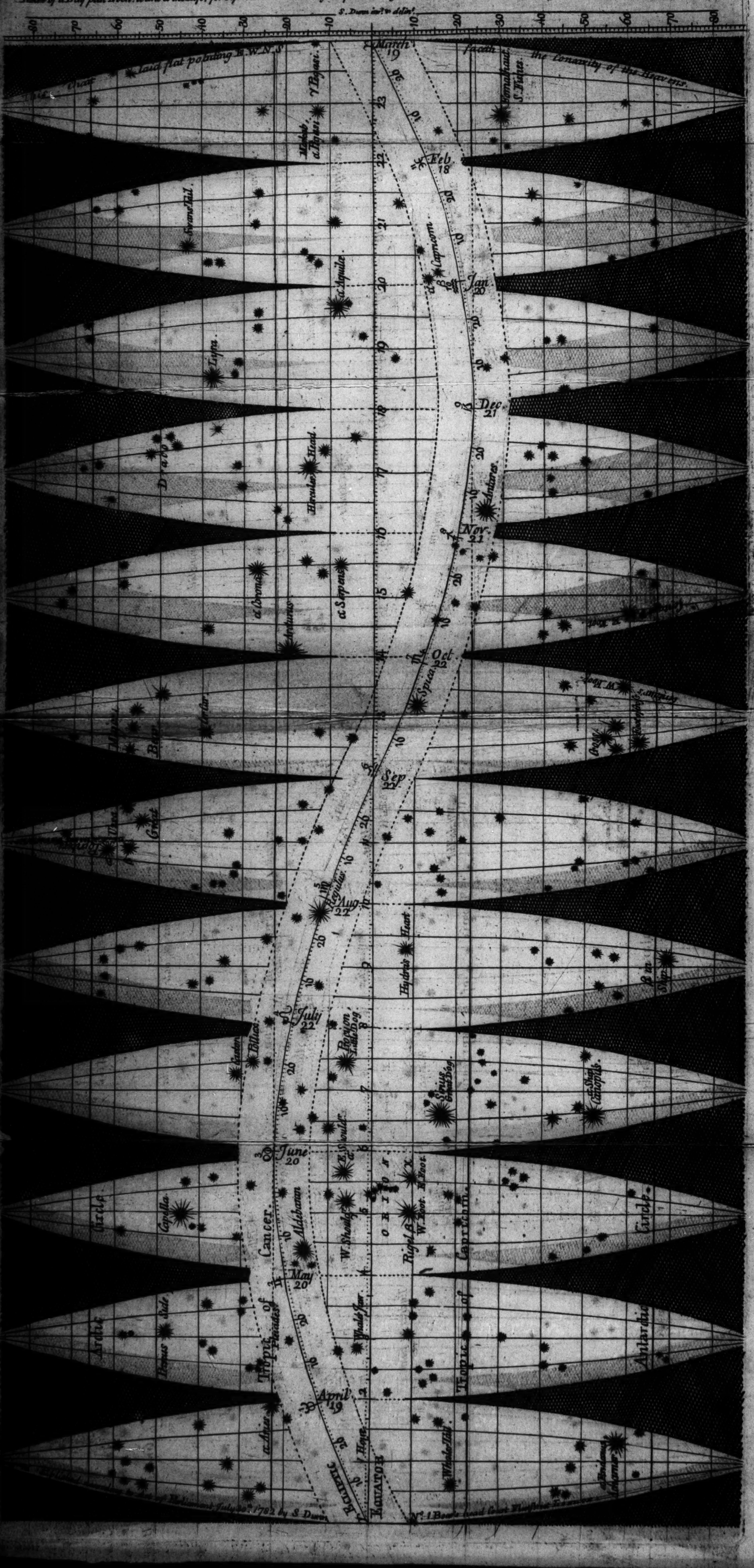
S. Dunn inv.t & delin.t



Published according to Act of Parliament July 17th 1782 by S. Dunn; No. 1 Boars head Court Fleetstreet London.

A CHART of the Zodiacal Stars used in finding the LONGITUDE at SEA; the 2d. Form. By S. DUNN; Teacher of the Mathematical Sciences.

Find the Sun, Moon & Planets Places in the Zodiac, by an Ephemeris; & their Positions to the Zodiacal Stars will appear by Inspection. For Hours of a Day past Noon, count to the Left; for before Noon to the Right of the Sun, gives the Stars on the Meridian. For farther see Treatise Longitude at Sea.

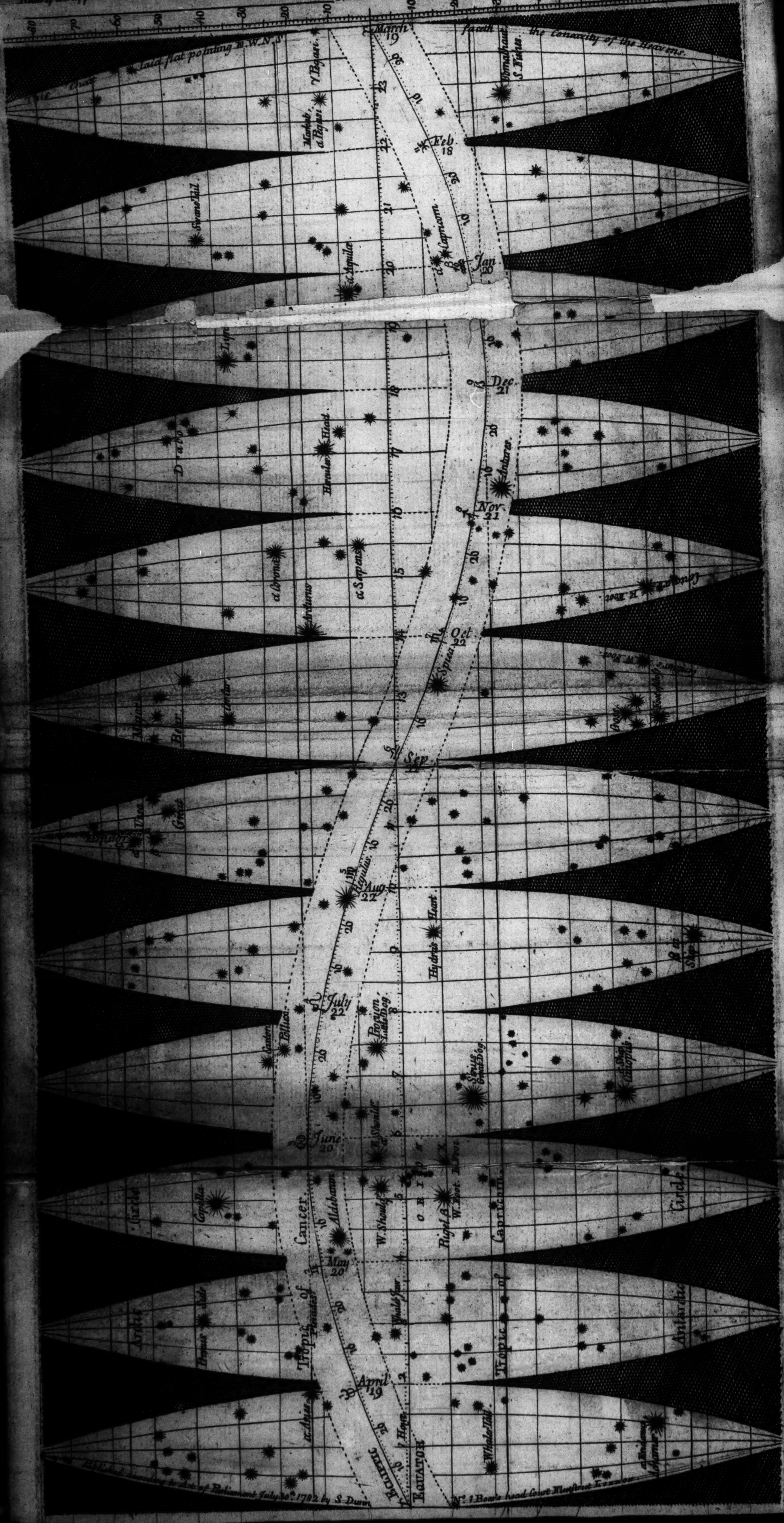


A CHART of the Zodiacal Stars used in finding the LONGITUDE at SEA; the 2d Form. By S. DUNN; Teacher of the Mathematical Sciences.

Find the Sun, Moon & Planets Places in the Zodiac, by an Ephemeris; to these Positions & the Zodiacal Stars will appear by Inspection.

Hours of a Day past Noon, count to the Left; for before Noon to the Right of the Sun, gives the Stars on the Meridian. For farther see Treatise Longitude at Sea.

S. Dunn inv.t & delin.t



Published according to Act of Parliament July 30th. 1782 by S. Dunn, No. 1 Boar's head Court Fleetstreet London.

A TABLE OF EQUATION OF TIME;

Shewing the SUN's *Southing, in* MEAN SOLAR TIME.

By S. Dunn.

Month Day	JANUARY				FEBRUARY				MARCH				APRIL			
	1776 1780	77 81	78 82	79 83	1776 1780	77 81	78 82	79 83	1776 1780	77 81	78 82	79 83	1776 1780	77 81	78 82	79 83
	h " "	"	"	"	h " "	"	"	"	h " "	"	"	"	h " "	"	"	"
1	12.4.1	21	14	7	12.14.3	8	6	4	12.12.31	34	37	40	12.3.45	47	52	57
2	12.4.28	49	42	35	12.14.10	15	14	12	12.12.18	21	24	27	12.3.25	29	34	38
4	12.5.24	44	38	31	12.14.23	26	25	24	12.11.51	54	58	1	12.2.49	53	58	2
6	12.6.17	37	31	24	12.14.32	34	33	32	12.11.23	26	29	33	12.2.14	18	22	27
8	12.7.9	28	22	16	12.14.37	39	38	38	12.10.52	56	59	3	12.1.39	43	48	52
10	12.7.59	17	11	5	12.14.40	40	40	40	12.10.20	24	28	32	12.1.6	10	14	18
12	12.8.46	4	58	52	12.14.40	39	39	39	12.9.48	52	55	59	12.0.34	38	41	45
14	12.9.31	28	42	37	12.14.36	34	35	35	12.9.13	18	22	26	12.0.3	6	10	14
16	12.10.14	29	24	19	12.14.30	27	28	29	12.8.38	42	47	51	11.59.33	37	40	44
18	12.10.53	7	3	58	12.14.21	16	17	19	12.8.2	7	11	15	11.59.5	8	12	15
20	12.11.30	43	38	34	12.14.9	3	5	6	12.7.26	30	35	39	11.58.39	42	45	48
22	12.12.3	15	11	7	12.13.54	47	49	51	12.6.49	53	58	2	11.58.14	17	20	23
24	12.12.34	44	41	37	12.13.36	29	31	34	12.6.12	16	21	25	11.57.51	54	57	59
26	12.13.1	10	7	4	12.13.17	9	11	14	12.5.34	39	43	48	11.57.30	33	35	38
28	12.13.25	33	30	27	12.12.55	46	49	52	12.4.57	2	6	11	11.57.11	14	16	18
30	12.13.45	52	50	48	--------	----	----	----	12.4.20	24	29	33	11.56.55	56	58	0
	MAY				JUNE				JULY				AUGUST			
1	11.56.47	49	51	53	11.57.27	25	23	21	12.3.26	23	21	18	12.5.50	51	52	53
2	11.56.40	42	43	45	11.57.36	34	32	30	12.3.37	35	32	29	12.5.46	47	48	50
4	11.56.27	29	30	32	11.57.56	54	52	49	12.3.59	57	54	52	12.5.36	37	39	40
6	11.56.17	18	20	21	11.58.17	15	12	10	12.4.19	17	15	13	12.5.24	25	27	29
8	11.56.9	10	11	12	11.58.40	37	34	32	12.4.38	36	34	32	12.5.9	11	13	15
10	11.56.4	4	5	6	11.59.3	1	58	55	12.4.56	54	52	50	12.4.52	54	56	58
12	11.56.0	1	1	2	11.59.27	25	22	19	12.5.11	9	8	6	12.4.32	35	37	40
14	11.55.59	1	0	0	11.59.52	49	46	44	12.5.25	23	22	20	12.4.10	13	16	19
16	11.56.1	1	1	0	12.0.18	15	12	9	12.5.37	35	34	33	12.3.47	50	53	56
18	11.56.4	4	3	3	12.0.44	41	38	35	12.5.46	45	44	43	12.3.21	24	28	31
20	11.56.10	9	9	8	12.1.9	6	3	0	12.5.54	53	52	52	12.2.53	57	0	4
22	11.56.18	17	16	15	12.1.35	32	29	26	12.5.59	59	58	58	12.2.24	27	31	35
24	11.56.28	27	25	24	12.2.1	58	55	52	12.6.2	2	2	2	12.1.52	56	0	4
26	11.56.40	39	37	36	12.2.26	23	20	17	12.6.3	3	3	3	12.1.19	24	28	32
28	11.56.54	52	51	49	12.2.51	48	45	42	12.6.1	1	2	2	12.0.45	49	54	58
30	11.57.9	8	6	4	12.3.14	12	9	6	12.5.57	58	58	59	12.0.9	14	18	22
	SEPTEMBER				OCTOBER				NOVEMBER				DECEMBER			
1	11.59.32	36	41	46	11.49.24	29	33	38	11.43.46	46	47	47	11.49.43	37	31	25
2	11.59.13	18	22	27	11.49.6	10	15	19	11.43.46	46	46	46	11.50.6	0	55	49
4	11.58.34	39	44	49	11.48.30	34	38	43	11.43.49	48	48	47	11.50.55	49	43	37
6	11.57.55	59	4	9	11.47.55	59	3	8	11.43.54	53	52	51	11.51.47	40	34	27
8	11.57.14	19	24	29	11.47.22	26	30	34	11.44.3	2	1	59	11.52.40	33	27	20
10	11.56.33	38	43	48	11.46.51	55	58	2	11.44.16	14	12	11	11.53.35	28	21	14
12	11.55.52	57	2	7	11.46.22	25	29	22	11.44.31	29	27	25	11.54.31	24	17	10
14	11.55.10	15	20	25	11.45.55	58	1	4	11.44.50	48	45	43	11.55.29	22	15	7
16	11.54.29	33	38	43	11.45.30	33	36	39	11.45.13	10	7	4	11.56.28	20	13	6
18	11.53.46	51	56	1	11.45.7	10	12	15	11.45.39	35	37	29	11.57.27	20	12	5
20	11.53.4	9	14	19	11.44.47	49	52	54	11.46.8	4	1	57	11.58.27	20	12	5
22	11.52.23	28	33	38	11.44.30	32	34	36	11.46.40	36	32	28	11.59.27	20	12	5
24	11.51.42	47	51	56	11.44.15	17	18	20	11.47.16	11	7	2	12.0.27	20	12	5
26	11.51.1	6	11	16	11.44.3	5	6	7	11.47.54	49	44	40	12.1.27	20	12	5
28	11.50.22	26	31	36	11.43.55	56	56	57	11.48.36	30	25	20	12.2.26	19	12	4
30	11.49.43	48	52	57	11.43.49	49	50	50	11.49.20	14	9	3	12.3.24	17	10	3
	1784	85	86	87	1784	85	86	87	1784	85	86	87	1784	85	86	87
	1788	89	90	91	1788	89	90	91	1788	89	90	91	1788	89	90	91
	1792	93	94	95	1792	93	94	95	1792	93	94	95	1792	93	94	95
	1796	97	98	99	1796	97	98	99	1796	97	98	99	1796	97	98	99

☞ *The Hours & Minutes read with the Seconds which do not belong to Bissextile Year.*

Published according to Act of Parliament January 24th 1777 By Samuel Dunn Maiden Lane, Covent Garden, LONDON.

A TABLE OF EQUATION OF TIME;
Shewing the SUN's *Southing, in* MEAN SOLAR TIME.

By S Dunn.

Month Day	JANUARY				FEBRUARY				MARCH				APRIL			
	1776. 1780.	77. 81.	78 82.	79. 83.	1776. 1780.	77 81.	78 82	79 83	1776. 1780.	77. 81.	78. 82.	79. 83.	1776. 1780.	77 81.	78 82.	79 83.
	h ′ ″	″	″	″	h ′ ″	″	″	″	h ′ ″	″	″	″	h ′ ″	″	″	″
1	12.4.1	21	14	7	12.14.3	8	6	4	12.12.31	34	37	40	12.3.43	47	52	57
3	12.4.56	17	10	3	12.14.17	21	20	18	12.12.5	8	11	14	12.3.7	11	16	20
5	12.5.51	11	4	58	12.14.27	31	30	28	12.11.37	40	44	47	12.2.31	36	40	44
7	12.6.44	3	57	50	12.14.35	37	36	35	12.11.7	11	15	18	12.1.56	1	5	9
9	12.7.34	53	47	41	12.14.39	40	40	39	12.10.37	40	44	48	12.1.23	26	31	35
11	12.8.23	41	35	29	12.14.40	40	40	40	12.10.4	8	12	16	12.0.50	53	57	1
13	12.9.9	26	20	15	12.14.38	37	37	38	12.9.30	35	39	43	12.0.18	22	26	29
15	12.9.53	8	3	58	12.14.34	31	32	32	12.8.56	0	4	9	11.59.48	51	55	59
17	12.10.34	48	44	39	12.14.25	22	23	24	12.8.20	25	29	34	11.59.19	22	26	29
19	12.11.12	25	21	16	12.14.14	10	11	13	12.7.44	49	53	58	11.58.52	55	58	1
21	12.11.47	59	55	51	12.14.2	56	57	59	12.7.7	12	16	21	11.58.26	29	32	35
23	12.12.19	30	26	22	12.13.45	39	41	43	12.6.30	35	39	44	11.58.2	5	8	11
25	12.12.47	57	54	51	12.13.27	19	21	24	12.5.53	58	2	7	11.57.41	43	46	48
27	12.13.13	22	19	16	12.13.6	58	0	3	12.5.16	20	25	29	11.57.21	23	25	28
29	12.13.35	43	40	38	12.12.45	……	……	……	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
31	12.13.54	1	59	56	……	……	……	……	12.4.2	6	11	15	……	……	……	……
	MAY				JUNE				JULY				AUGUST			
1	11.56.47	49	51	53	11.57.27	25	23	21	12.3.26	23	21	18	12.5.50	51	52	53
3	11.56.33	35	37	38	11.57.46	44	42	40	12.3.48	46	43	41	12.5.41	43	44	45
5	11.56.22	23	25	26	11.58.7	4	2	0	12.4.9	7	5	2	12.5.30	32	33	35
7	11.56.13	14	15	16	11.58.28	26	23	21	12.4.29	27	25	22	12.5.16	18	30	22
9	11.56.6	7	8	9	11.58.51	49	46	43	12.4.47	45	43	41	12.5.1	3	5	7
11	11.56.2	2	3	3	11.59.15	12	10	7	12.5.4	2	0	58	12.4.42	44	47	49
13	11.55.59	0	0	0	11.59.40	37	34	31	12.5.18	17	15	13	12.4.21	24	27	29
15	11.56.0	0	0	0	12.0.5	2	59	56	12.5.31	30	28	27	12.3.59	2	5	8
17	11.56.2	2	1	1	12.0.31	28	25	22	12.5.42	41	39	38	12.3.34	37	40	43
19	11.56.7	6	6	5	12.0.56	54	51	48	12.5.50	50	49	48	12.3.7	11	14	17
21	11.56.14	13	12	11	12.1.22	19	16	13	12.5.57	56	55	55	12.2.39	42	46	50
23	11.56.23	21	21	19	12.1.48	45	42	39	12.6.1	1	0	0	12.2.8	12	16	20
25	11.56.34	32	31	30	12.2.13	11	8	5	12.6.3	3	3	3	12.1.36	40	44	48
27	11.56.47	45	44	42	12.3.38	37	33	30	12.6.2	2	3	3	12.1.2	6	11	15
29	11.57.1	0	58	56	12.3.3	0	57	54	12.6.0	0	0	1	12.0.27	31	36	40
31	11.57.18	16	14	12	……	……	……	……	12.5.54	55	56	56	11.59.51	55	0	4
	SEPTEMBER				OCTOBER				NOVEMBER				DECEMBER			
1	11.59.32	36	41	46	11.49.24	29	33	38	11.43.46	46	47	47	11.49.43	37	31	25
3	11.58.54	58	3	8	11.48.48	52	56	1	11.43.47	47	46	46	11.50.31	25	19	12
5	11.58.15	19	24	29	11.48.12	16	21	25	11.43.51	50	50	49	11.51.21	14	8	2
7	11.57.34	39	44	49	11.47.38	42	46	51	11.43.58	57	56	55	11.52.13	6	0	53
9	11.56.54	59	4	9	11.47.6	10	14	18	11.44.9	7	6	4	11.53.7	0	54	47
11	11.56.12	17	22	28	11.46.36	40	43	47	11.44.23	21	19	17	11.54.3	56	49	42
13	11.55.31	36	41	46	11.46.8	11	14	18	11.44.40	38	36	33	11.55.0	53	46	39
15	11.54.49	54	59	4	11.45.42	45	48	51	11.45.1	58	56	53	11.55.38	51	44	37
17	11.54.7	12	17	22	11.45.18	21	24	26	11.45.25	22	19	16	11.56.57	50	43	35
19	11.53.25	30	35	40	11.44.57	59	2	4	11.45.53	49	46	42	11.57.57	50	42	35
21	11.52.43	48	53	58	11.44.38	40	42	44	11.46.24	20	16	12	11.58.57	50	42	35
23	11.52.2	7	12	17	11.44.22	24	26	28	11.46.58	53	49	45	11.59.57	50	43	35
25	11.51.21	26	31	36	11.44.9	10	12	13	11.47.35	30	25	20	12.0.57	50	43	35
27	11.50.41	46	51	56	11.43.59	0	1	2	11.48.15	10	4	59	12.1.57	49	42	35
29	11.50.2	7	12	16	11.43.51	52	53	54	11.48.57	52	46	41	12.2.55	48	40	34
31	……	……	……	……	11.43.47	47	48	48	……	……	……	……	12.3.53	46	39	32
	1784. 1788. 1792. 1796.	85. 89. 93. 97.	86. 90. 94. 98.	87. 91. 95. 99.	1784. 1788. 1792. 1796.	85. 89. 93. 97.	86 90 94 98	87. 91. 95. 99.	1784. 1788. 1792. 1796.	85. 89. 93. 97.	86 90 94 98	87. 91. 95 99	1784. 1788. 1792. 1796.	85. 89. 93. 97.	86. 90. 94. 98.	87. 91. 95. 99.

☞ *The Hours & Minutes read with the Seconds which do not belong to Bissextile Years.*

Published according to Act of Parliament September 11th 1776. By Samuel Dunn Maiden Lane Covent Garden LONDON.

The Points & Degrees of the Compass Card, to Halfquarter Points; By S Dunn.

		Points	D. M	D. M.					Points	D. M	D. M		
North	South	0 .	0 . 0	0 . 0	North	South	N. E.	S. E.	4 .	45 . 0	--------	N. W.	S W
		0 ⅛	--------	1 . 24					4 ⅛	--------	46 . 25		
		0 ¼	2 . 49	--------					4 ¼	47 . 49	--------		
		0 ⅜	--------	4 . 13					4 ⅜	--------	49 . 13		
		0 ½	5 . 37	--------					4 ½	50 . 37	--------		
		0 ⅝	--------	7 . 2					4 ⅝	--------	52 . 2		
		0 ¾	8 . 26	--------					4 ¾	53 . 26	--------		
		0 ⅞	--------	9 . 51					4 ⅞	--------	54 . 51		
N. by E.	S. by E	1 .	11 . 15	--------	N. by W.	S. by W.	N. E b E.	S. E b E.	5 .	56 . 15	--------	N. W b W.	S. W b W.
		1 ⅛	--------	12 . 40					5 ⅛	--------	57 . 40		
		1 ¼	14 . 4	--------					5 ¼	59 . 4	--------		
		1 ⅜	--------	15 . 28					5 ⅜	--------	60 . 28		
		1 ½	16 . 52	--------					5 ½	61 . 52	--------		
		1 ⅝	--------	18 . 17					5 ⅝	--------	63 . 17		
		1 ¾	19 . 41	--------					5 ¾	64 . 41	--------		
		1 ⅞	--------	21 . 6					5 ⅞	--------	66 . 6		
N. N. E.	S. S. E.	2 .	22 . 30	--------	N. N. W.	S. S. W.	E. N. E.	E. S. E.	6 .	67 . 30	--------	W. N. W.	W. S. W.
		2 ⅛	--------	23 . 55					6 ⅛	--------	68 . 55		
		2 ¼	25 . 19	--------					6 ¼	70 . 19	--------		
		2 ⅜	--------	26 . 43					6 ⅜	--------	71 . 43		
		2 ½	28 . 7	--------					6 ½	73 . 7	--------		
		2 ⅝	--------	29 . 32					6 ⅝	--------	74 . 30		
		2 ¾	30 . 56	--------					6 ¾	75 . 56	--------		
		2 ⅞	--------	32 . 20					6 ⅞	--------	77 . 21		
N. E b N.	S. E b S.	3 .	33 . 45	--------	N. W b N.	S. W b S.	E by N	E. by S	7 .	78 . 45	--------	W. by N.	W. by S.
		3 ⅛	--------	35 . 10					7 ⅛	--------	80 . 10		
		3 ¼	36 . 34	--------					7 ¼	81 . 34	--------		
		3 ⅜	--------	37 . 59					7 ⅜	--------	82 . 58		
		3 ½	39 . 22	--------					7 ½	84 . 22	--------		
		3 ⅝	--------	40 . 47					7 ⅝	--------	85 . 47		
		3 ¾	42 . 11	--------					7 ¾	87 . 11	--------		
		3 ⅞	--------	43 . 36					7 ⅞	--------	88 . 36		
N. E.	S. E	4 .	45 . 0	--------	N. W.	S. W.	East .	East .	8 .	90 . 0	--------	West .	West .

Published according to Act of Parliament July 27th 1782 by Samuel Dunn Fleetstreet London.

S. Dunn invt. & delint.

The Right Aſcensions and Declinations of Fixed Stars, By S. Dunn.

1785.	R.t Aſc.	2.4.6.8.10 Years.	Declination.		2.4.6.8.10 Years.
	° ′	, change ,	° ′		, change ;
α Eridanus	22. 25.	1.2.4.5.6.	58.19	S.	1.1.2.2.3 sub.
α Whale's Jaw.	42.46.	2.3.5.6.8.	3.14	N.	1.1.1.2.2:add.
α Perſeus	47.17.	2.4.6.8.10.	49. 5	N.	0.1.1.2.2:add.
α Aldebaran ..	65.54.	1.3.5.7.9.	16. 4	N.	0.1.1.1.1:add.
α Capella	75.12.	2 4 7 9 11	45 46	N.	0.0.1.1.1:add.
β Rigel	76. 3.	1.3.4.6.7.	8.27	S.	0.0.1.1.1:sub.
γ Orion	78.24.	2.3.5.6.8.	6. 8	N.	0.0.0.0.1:add.
α Orion	85.54.	2.3.5.6.8.	7.21	N.	0.0.0.0.0.
α Canopus	94.48.	1.1.2.3.3.	52.35	S.	0.0.0.0.0.
α Sirius	98.56.	1.2.4.5.7.	16.25	S.	0.0.0.0.1:add.
α Caſtor	110.12.	2.4.6.8.10.	32.21	N.	0.0.1.1.1:sub.
α Procyon	112. 1.	2.3.5.6.8.	5.46	N.	0.1.1.1.1:sub.
β Pollux	113. 3.	2.4.6.8.9.	28.32	N.	0.1.1.1.1:sub.
β Ship	137.42.	0.1.1.1.2.	68.50	S.	0.1.1.2.3:add.
α Hydra	139.16.	2.3.4.6.7.	7.45	S.	1.1.2.2.3:add.
α Regulus	149.14.	2.3.5.6.8.	13. 0	N.	1.1.2.2.3:sub.
β S. Pointer ...	162. 2.	2.4.6.7.9.	57.32	N.	1.1.2.3.3.sub.
α N. Pointer ...	162.34.	2.4.6.8.10.	62.54	N.	1.1.2.3.3.sub.
α Croſs	183.43.	2.3.5.6.8.	61.55	S.	1.1.2.3.3.add.
α Spica	198.29.	2.3.5.6.8.	10. 2	S.	1.1.2.3.3.add.
α Arcturus ...	211.29.	1.3.4.6.7.	20.22	N.	1.1.2.2.3.sub.
α Centaur	216.21.	2.4.7.9.11.	59.57	S.	1.1.2.2.3.add.
α Antares	244. 4.	2.4.5.7.9.	25.56	S.	0.1.1.1.2.add.
α Lyra	277.25.	1.2.3.4.5.	38.36	N.	0.0.0.0.0.
α Aquilæ	295. 5.	1.3.4.6.7.	8.19	N.	0.1.1.1.1.add.
α Fomalhaut.	341.26.	2.3.5.7.8.	30.45	S.	1.1.2.3.3.sub.
α Markab	343.31.	1.3.4.6.7.	14. 4	N.	1.1.2.3.3.add.
γ Pegaſus	0.33	2.3.5.6.8.	13.59	N.	1.1.2.2.3.add.
α Pole Star	12.14.	6.11.17.23.29.	88.10	N.	1.1.2.3.3.add.

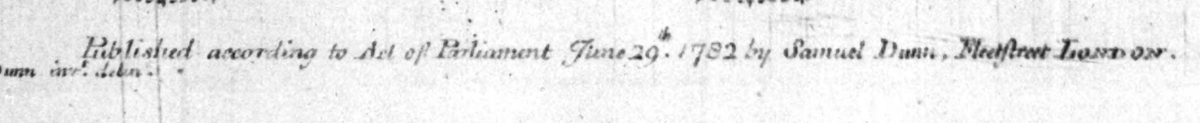
The Change for Years, added to R.t Aſc. gives the R.t Aſc. required.

The Change for Years, applied to Decl.n give the Decl.n required.

Note.

The Change in R.t Aſc.n is additive. The Change in Declination is as it is written.

A Miniature Sketch of the Lines in the Chart of Zodiacal Stars.



Published according to Act of Parliament June 29th 1782 by Samuel Dunn, Fleetſtreet London.

S. Dunn inv.t delin.

A Table of REFRACTION in ALTITUDE, by S. Dunn, Teacher of Mathematics LONDON.

Alt.^{d}		Refrac.^{n}	Alt.^{d}		Refrac.^{n}	Alt.^{d}		Refrac.^{n}	Alt.^{d}		Refrac.^{n}	Alt.^{d}		Refrac.^{n}	Alt.^{d}		Refrac.^{n}	Alt.^{d}		Refrac.^{n}	Alt.^{d}		Refrac.^{n}
°	′	′ ″	°	′	° ′	°	′	′ ″	°	′	′ ″	°	′	′ ″	°	′	′ ″	°	′	′ ″	°	′	′ ″
	.0	34.27		.30	28.57	1.	0	24.32	3.	0	14.28	5.	0	9.40	8.		6.24	37.		1.12	66.		.25
	.1	34.15		.31	28.47		.4	24.3		.4	14.12		.6	9.28	9.		5.43	38.		1.9	67.		.23
	.2	34.3		.32	28.37		.8	23.35		.8	13.56		.12	9.16	10.		5.10	39.		1.7	68.		.22
	.3	33.51		.33	28.28	Diff^{ce} of Refrac.^{n} for 4′ Altitude 25″	.12	23.8	Diff^{ce} of Refrac.^{n} for 4′ Altitude 13″	.12	13.44	For 6′ Alt. 14″	.18	9.4	11.		4.43	40.		1.5	69.		.21
	.4	33.39		.34	28.18		.16	22.42		.16	13.32		.24	8.56	12.		4.19	41.		1.2	70.	Here the Differences of Refraction are for 60′ Altitude	.20
	.5	33.27		.35	28.9		.20	22.17		.20	13.20		.30	8.51	13.		3.58	42.		1.0	71.		.19
	.6	33.15		.36	27.59		.24	21.52		.24	13.8		.36	8.45	14.	Here the Differences of Refraction are for 60′ Altitude	3.40	43.		.58	72.		.18
	.7	33.3		.37	27.49		.28	21.28		.28	12.56		.42	8.39	15.		3.24	44.		.56	73.		.17
Diff^{ce} of Refraction for each Minute of Altitude 11″	.8	32.51	Diff^{ce} of Refraction for each Minute of Altitude 9″	.38	27.40		.32	21.4		.32	12.44		.48	8.33	16.		3.9	45.		.54	74.		.16
	.9	32.40		.39	27.31		.36	20.40		.36	12.32		.54	8.27	17.		2.56	46.		.52	75.		.15
	.10	32.29		.40	27.23		.40	20.16		.40	12.20	6.	0	8.21	18.		2.45	47.		.51	76.		.14
	.11	32.17		.41	27.13		.44	19.52		.44	12.12		.6	8.10	19.		2.35	48.		.49	77.		.13
	.12	32.6		.42	27.4		.48	19.31		.48	12.4	For 6′ Alt. 8″	.12	8.4	20.		2.26	49.		.47	78.		.12
	.13	31.55		.43	26.55		.52	19.11		.52	11.56		.18	7.58	21.		2.18	50.		.46	79.		.11
	.14	31.44		.44	26.46		.56	18.51		.56	11.48		.24	7.52	22.		2.11	51.		.44	80.		.10
	.15	31.33		.45	26.37	2.	0	18.31	4.	0	11.40		.30	7.46	23.		2.5	52.		.42	81.		.9
	.16	31.22		.46	26.28		.4	18.15		.4	11.32		.36	7.39	24.		2.0	53.	Here the Differences of Refraction are for 60′ Altitude	.41	82.		.8
	.17	31.11		.47	26.19	Diff^{ce} of Refrac.^{n} for 4′ Altitude 18″	.8	17.56	Diff^{ce} of Refrac.^{n} for 4′ Altitude 16″	.8	11.24		.42	7.33	25.		1.55	54.		.39	83.		.7
	.18	31.0		.48	26.10		.12	17.36		.12	11.16		.48	7.27	26.		1.50	55.		.38	84.		.6
	.19	30.49		.49	26.2		.16	17.16		.16	11.8		.54	7.21	27.		1.46	56.		.37	85.		.5
	.20	30.39		.50	25.54		.20	16.57		.20	11.0	7.	0	7.15	28.		1.41	57.		.35	86.		.4
	.21	30.29		.51	25.45		.24	16.39		.24	10.52		.6	7.9	29.		1.37	58.		.34	87.		.3
	.22	30.18		.52	25.36		.28	16.21		.28	10.44	For 6′ Alt. 8″	.12	7.3	30.		1.33	59.		.33	88.		.2
	.23	30.8		.53	25.27		.32	16.3		.32	10.36		.18	6.57	31.		1.29	60.		.31	89.		.1
	.24	29.57		.54	25.18		.36	15.47		.36	10.28		.24	6.51	32.		1.26	61.		.30	90.		.0
	.25	29.47		.55	25.10		.40	15.31		.40	10.20		.30	6.45	33.		1.23	62.		.29	* Between N^{o} 65 & 66. Fleet street.		Removed from Clements Inn and from Maiden Lane.
	.26	29.37		.56	25.2		.44	15.25		.44	10.12		.36	6.39	34.		1.20	63.		.28			
	.27	29.27		.57	24.54		.48	15.9		.48	10.4		.42	6.33	35.		1.17	64.		.27			
	.28	29.17		.58	24.46		.52	14.53		.52	9.56		.48	6.27	36.		1.14	65.		.26			
	.29	29.7		.59	24.39		.56	14.40		.56	9.48		.54	6.24									

Published according to Act of Parliament July 14th 1780, by S. Dunn N^{o} 1. Boars-head Court * Fleet street.

A Formula for Latitude, having aſſumed Latitudes, & Elaps'd Time, By S. Dunn.

1st. Lat L.
Co.lat. Co.ar.
Polar d. Co.ar.
1st. Co.alt.
2)
½ Sum Sine
Remr. Sine
2)
Cosine
2
B =

2d. Lat. l.
Co.lat. Co.ar.
Polar d. Co.ar.
1st. Co.alt.
2)
½ Sum Sine
Remr. Sine
2)
Coſine
2
E =

1st. Lat L.
Co.lat. Co.ar.
Polar d. Co.ar.
2d. Co.alt.
2)
½ Sum Sine
Remr. Sine
2)
Coſine
2
A =
B = add or ſub. A & B to give C, nearest to Q.
C =
C = for 1st. Lat.
F = for 2d. Lat.
G = Diff. H = Diff.
G = : H :: I : K.

2d. Lat. l.
Co.lat. Co.ar.
Polar d. Co.ar.
2d. Co.alt.
2)
½ Sum Sine
Remr. Sine
2)
Coſine
2
D =
E = add or ſub. D & E to give F. nearest to Q.
F =
Q = Elapsed Time.
I = Diff. Q & C or Q & F.
K = Correcn. for L or l.

1st. The aſsumed Co-latitudes, Polar-distances, & Co-altitudes, must be such, that any two of them together, must be more than the third. 2d. Co.ar. is Coſecant, leſs Index 10. & Log. of more than 90°. is Log. of Suppt. to 180°. 3d When the true Lat. is between those aſſumed, the Correction converges fast to Truth. 4th. When L is true, B is true Time of 1st. Alt. & A true Time of 2d. Alt. from Noon. The like for E & D. 5th. For Azimuth, work as above, with Co-lat, Co alt. & Polar dist. this gives Azimuth from North in N. Lat. & from South in S. Lat. 6th. When the same Lat. repetes, the Lat. Times & Azimuths are correct.

Published according to Act of Parliament June 29th. 1782 by Samuel Dunn, Fleetſtreet London.

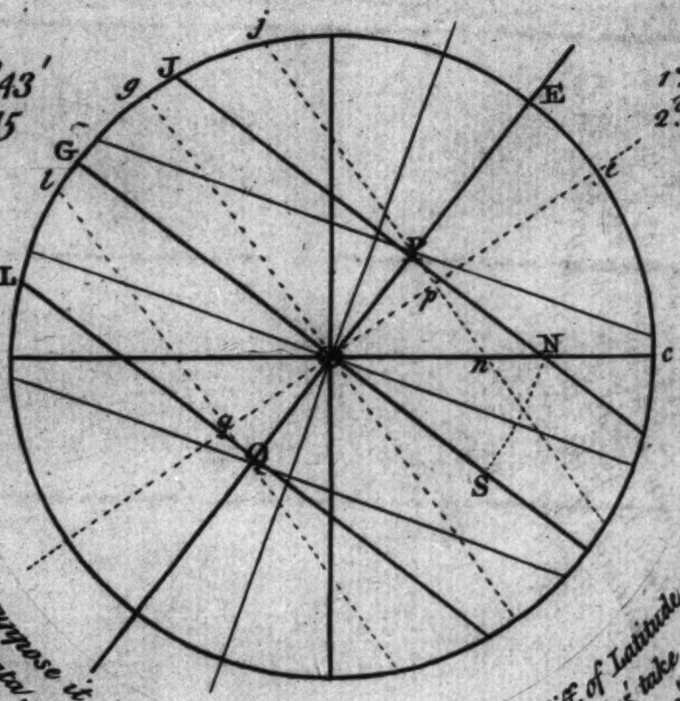
S. Dunn invt. delint.

Data.

Polar dist. 78°.43'
Elap. time 21.15

Data.

1.st Co alt. 43°.5'
2.d Co alt. 35.53



Assume the Latitude twice, as suppose it is 46°.20' or 46°.36', with which & the Data, get the two hour Angles, & the false elapsed times will be 20°.34' & 21°.42', the diff. is 68' & the diff. of Latitude 16'. From the true elapsed time 21°.15' take 20°.34' remains 41'. As 68 to 16' so 41' to 10', which added to 46°.20' gives 46°.30' the true Latitude of the Place required.

Calculation.

Lat.	46 . 20		
Co.lat.	43 . 40	Co.ar.	0 . 16086
à Pole	78 . 43	Co.ar.	0 . 00848
Co.alt	43 . 5		
2	165 . 28		
	82 . 44	Sine	9 . 99650
	39 . 39	Sine	9 . 80489
		2	19 . 97073
	14 . 47		9 . 98536
∠	29 . 34	is 20°.34' Diff.	

Lat.	46 . 20		
Co.lat.	43 . 40	Co.ar.	0 . 16086
à Pole	78 . 43	Co.ar	0 . 00848
Co.alt.	35 . 53		
2	158 . 16		
	79 . 8	Sine	9 . 99214
	43 . 15	Sine	9 . 83581
		2	19 . 99729
	4 . 30		9 . 99864
∠	9 . 0		

Lat.	46 . 36		
Co. lat.	43 . 24	Co. ar.	0 . 16299
à Pole	78 . 43	Co. ar.	0 . 00848
Co. alt	43 . 5		
2	165 . 12		
	82 . 36	Sine	9 . 99637
	39 . 31	Sine	9 . 80366
		2	19 . 97150
	14 . 36		9 . 98575
∠	29 . 12	is 21°.42' Diff.	

Lat.	46 . 36		
Co. lat.	43 . 24	Co. ar	0 . 16299
à Pole	78 . 43	Co. ar	0 . 00848
Co. alt	35 . 53		
2	158 . 0		
	79 . 0	Sine	9 . 99195
	43 . 7	Sine	9 . 83473
		2	19 . 97815
	3 . 45		9 . 99907
∠	7 . 30		

Published as the Act directs July . 1. 1778, by S. Dunn.

A New FORMULA for LATITUDE, having, Sights of the Sun, Elaps'd Time and Equal Declination. By S. Dunn.

° ′ ° ′

l = Latitude by Reckoning -- .
d = Declination ---------- .
n = Alt.^d ☉ far a Meridian --- .
B = Co-declination -------- .
N = Alt.^d near Meridian ---- .
Q = Elapsed Time -------- .

O = Co-latitude ----- . Co.ar. ′
p = Polar dist ------ . Co.ar. ′
a = Co Alt ----- . ′
sum 2) . ′
½ Sum. . Sine
Rem.^r -- . Sine 2) ′
. Cosine ′

2

t = .
Q = .
T = . Sine ′
d = . Cosine ′
G = . Sine ′
d = . Sine ′
G = . Secant ′
A = . Cosine ′
N = . Sine ′
G = . Secant ′
D = . Cosine ′

A = .
B = .
C = . add if *p* is under 90° else sub.
D = .
E = . Zenith dist.
d = . Declination.
. Latitude.

Farther Calculations.

Co-latitude

Published according to Act of Parliament July 27th 1782 by Samuel Dunn Fleetstreet London.

S. Dunn inv.t & delin.t

A New FORMULA for LATITUDE, having Sights of the Sun, & Elaps'd Time; By S. Dunn.

° ′ ° ′

l = Latitude by Reckoning ....
d = Decl.n ☉ for a Meridian ....
n = Alt.d ☉ for a Meridian ....

F = Decl.n ☉ near Meridian ....
B = Comp.t ☉ Declination ....
P = Polar dist. ☉ near Merid.n ....
N = Alt. ☉ near Meridian ....
b = Co-alt. ☉ near Merid.n ....

H ′ ″

Q = Elaps'd Time .... = .
1st Obs.n .... =
2d .... = .
3d .... =
4th .... =
5th .... =
6th .... =
7th .... =

O = Co-latitude ..... . Co.ar ... .
p = Polar dist .... Co.ar .... .
a = Co-alt . ... . .
2 . .
Sum
½ Sum . Sine ... .
Rem.r . Sine ... 2
. Cosine --- .
2
t = ...
Q = ...
T = ... Sine .... .
F = ... Cosine ... .
G = ... Sine ... .
F = ... Sine ... .
G = ... Secant ..
A = ... Cosine ...
N = ... Sine ...
G = ... Secant ..
D = .. . Cosine ...
.
A = ...
B = ...
C = ... add if P is under 90°. else sub.
D = ...
E = ... Zenith dist. for F.
F = ... Declination.
. Latitude.
L = ... Co-latitude.

NB. 1st The Observation for a Meridian may be at any time of the Day; the other should be as near the Meridian as it can be judged of & taken. 2d. Co-ar is Cosecant less Index 10. & Log. of more than 90°. is Log. of Supplement to 180°. 3d. When d & F are equal, then p & P are equal. 4th If Decl.n & Lat. are both North or both South, subtract Decl.n from 90°. but if otherwise, add Decl.n to 90°. to get Polar distance.

Haght Fet.	Dip ′	Haght Fet.	Dip ′		Alt. ° ′ Ref. ″	Alt. ° ′ Ref. ″	Alt. ° ′ Ref. ″	Alt. ° ′ Ref. ″	Alt. ° ′ Ref. ″	Alt. ° ′ Ref. ″
1	1	43	7		. 7 = 33	. 42 = 27	1 . 33 = 21	2 . 50 = 15	5 : 20 = 9	17 . 0 = 3
3½	2	57	8		. 12 = 32	. 49 = 26	1 . 43 = 20	3 . 7 = 14	6 . 15 = 8	24 . 0 = 2
8	3	72	9		. 18 = 31	. 50 = 25	1 . 54 = 19	3 . 27 = 13	7 . 15 = 7	47 . 0 = 1
14½	4	89	10		. 24 = 30	1 . 4 = 24	2 . 7 = 18	3 . 50 = 12	8 . 35 = 6	90 . 0 = 0
22	5				. 30 = 29	1 . 13 = 23	2 . 19 = 17	4 . 20 = 11	10 . 15 = 5	
					. 36 = 28	1 . 23 = 22	2 . 33 = 16	4 . 50 = 10	13 . 0 = 4	

Published according to Act of Parliament May 20th. 1782 by Samuel Dunn, Fleetstreet, LONDON.

S. Dunn inv.t & delin.t

A New FORMULA for LATITUDE having Sights of STARS, By S. Dunn.

✳ ° '

l = Latitude by Reckoning --- .
d = Decl.n ✳ far à Meridian ---- .
n = Alt. ✳ far à Meridian ----- .

●

F = Decl.n ● near Meridian --- .
B = Compl.t ●'s Declination ---- .
P = Polar-diſtance of ● ------- .
N = Alt. ● near Meridian ----- .
b = Complement of ● Alt ----- .

✳'s Right Aſcenſion ------- .
●'s Right Aſcenſion ------- .
Q = ✳ & ● Equator.l diſtance ---- .

NB. 1.st ● should be obſerved as near the Meridian as poſsible. 2.d The Altitudes of ✳ & ● should be clear'd from Dip & Refraction. 3.d C is the Difference of A & B. 4.th When l is the true Latitude, t is the true Distance of ✳ from Meridian & T that of ●. 5.th When t is leſs than Q the Altitudes were on different Sides of the Meridian. 6.th When t is greater than Q the Altitudes were on the same Side of the Meridian. 7.th As O, p, a, are used to find t; so use L, p, a, to find t correct & then T correct. 8.th So use l, a, p, or rather use L, a, p, to find ✳'s true Azimuth; & l, b, P, or rather L, b, P, to find ●'s true Azimuth. 9.th Co-ar. is Co-ſecant leſs Index 10. & Log. of more than 90°. is Log. of Supplement to 180°.

° '

O = Co-latitude --- . Co-ar. -- .
p = Polar dist ✳. . Co-ar. -- .
a = Co-alt. ✳
sub. 2 .
½ Sum . Sine 2
Rem.r . Sine .
. Coſine .
2
t = ...
Q = ...
T = ... Sine --- .
F = ... Coſine .
G = ... Sine -- .
F = ... Sine -- .
G = ... Secant .
A = ... Coſine .
N = ... Sine --- .
G = ... Secant .
D = ... Coſine .

A = ...
B = ...
C = ... add if P is under 90°. elſe sub.
D = ...
E = ... ● Zenith distance.
F = ... ● Declination.
. Latitude.
L = ... Colatitude.

Height Feet	Dip '	Height Feet	Dip '	Alt. ° '	Ref. '	Alt. ° '	Ref. '	Alt. ° '	Ref. ''	Alt. ° '	Ref. '	Alt. ° '	Ref. '	Alt. ° '	Ref. '
1	1	43	7	. 7	33	. 42	27	1 . 33	21	2 . 50	15	5 . 20	9	17 . 0	3
3½	2	57	8	. 12	32	. 40	26	1 . 43	20	3 . 7	14	6 . 15	8	24 . 0	2
8	3	72	9	. 18	31	. 56	25	1 . 54	19	3 . 27	13	7 . 15	7	47 . 0	1
14½	4	89	10	. 24	30	1 . 4	24	2 . 7	18	3 . 50	12	8 . 35	6	90 . 0	0
22	5			. 30	29	1 . 13	23	2 . 19	17	4 . 20	11	10 . 15	5		
				. 36	28	1 . 23	22	2 . 33	16	4 . 50	10	13 . 0	4		

Published according to Act of Parliament May 20th 1782 by Samuel Dunn, Fleetstreet LONDON.

S. Dunn inv.t & delin.t

13

A New FORMULA for LATITUDE having Sights of Sun & Moon; By S. Dunn.

° ′ ° ′

l = Latitude by Reckoning ....

d = Decl^{n}. ● or ☽ far à Merid^{n}. ....

n = Alt. ● or ☽ far à Merid^{n}. ....

F = Decl. ☽ or ● near Merid^{n}. ....

B = Comp^{t}. ☽ or ● Declination. ....

P = Polar dist. ☽ or ● near Merid^{n}. ....

N = Altitude ☽ or ● near Merid^{n}. ....

b = Co-alt. ☽ or ● near Merid^{n}. .

R^{t} Asc^{n}. ● or ☽ far à Merid^{n}. ....

R^{t} Asc ☽ or ● near Merid^{n} ....

Q = ● & ☽ Equator^{l}. distance ....

Preparations.

Obs^{d}. Alt. ● lower Limb ....

Semid^{r}. ′ Dip ′ Ref^{n}. ′ is .

True Alt. ● Centre ....

Obs^{d}. Alt. ☽ lower or upper Limb. .

Semid^{r}. ′ Dip ′ Ref^{n}. ′ is .

: — Cosine .... ″ M = .

: ☽ Hor. Par^{x}. = .

: ☽ Par^{x}. Alt^{d}. add .

Obs^{d}. Alt. ☽ Centre. .... M = .

True Alt. ☽ Centre. ....

☽ true Declination ....

☽ true Polar dist. ....

● true Right Ascension. ....

☽ true Right Ascension. ....

● & ☽ Equator^{l}. distance. ....

● Declination ....

″ ′

O = Co-latitude .... Co ar. .

p = Polar dist .... Co ar. .

a = Co-alt ....

Sum 2) . .

½ Sum . Sine .

Rem^{r}. . Sine 2) .

Cosine .

. 2 .

t = ...

Q = ...

T = ... Sine .

F = ... Cosine .

G = ... Sine .

F = ... Sine .

G = ... Secant .

A = ... Cosine .

N = ... Sine .

G = ... Secant .

D = ... Cosine .

A = ...

B = ...

C = ... add if P is under 90°. else sub.

D = ...

E = ... ☽ or ● Zenith dist.

F = ... ☽ or ● Declination.

. Latitude.

L = ... Co-latitude.

NB. When a zodiacal Star or any other is used instead of the Sun, the Star's R^{t}. Ascension must be compared with the Sun's R^{t}. Ascension at the time of Observation, to get the Solar Time of Observation. Either ● or ☽ may be nearest to the Meridian, but the Time is best computed from the Sun when ● is farthest from Meridian. Coar. is Co-secant less Index 10. & Log. of more than 90°. is Log. of Supplement to 180°. When lower Limb is taken add Semid^{r}. & sub. Dip & Ref^{n}. When upper Limb is taken, sub. Semid^{r}. Dip & Ref^{n}.

13

Published according to Act of Parliament May 20th. 1782 by Samuel Dunn, Fleetstreet LONDON.

S. D[illegible] inv^{t}. & delin^{t}.

LONGITUDE Instructions; By S. Dunn.

• 1. Get the Altitude of the Sun's Centre cleared from Dip & Semidiameter, the Altitude of the Moon's Centre cleared from Dip & Semidiameter, & the Sun & Moon's nearest Limbs. ..... Add 32′ to the observed Distance of Limbs to get the Rough Central Distance. with this from Ephemeris page 8, 9, 10 or 11 for the Month, where the Day of the Month & Sun are together take out the nearest Hour; this is the rough Hour for Greenwich.

2. The Ephemeris has the

Sun's true Semidiameter .... page	3.
Moon's true Semidiameter	7.
Moon's Horizontal Parallax	7.
Three hourly Distances	8, 9. 10. 11.
Sun's true Declination	2.

The Requisite Tables have the

Seconds for Moon's Altitude .. page	153.
Refraction in Altitude	2.
Moon's Parallax in Altitude	3, 4, 5.
Time & Degrees	6.

3. Begin the Formula with the Rough Central Distance & Rough Hour for Greenwich, & go on as it directs until you come to the Number E in it. Then, in usual Cases, the nearer the Rough Central Distance in Degrees, comes to 120°, the greater it is; & the nearer it comes to 20°, the leſs it is. A great Altitude of the Moon may be that above 20°. When the Rough Central Distance in Degrees is great, & especially, when the Moon's Altitude is also great; then Number E may be written for the true Distance of Centres.

4. For small Distances, or small Moon's Altitude; Take the Moon's Parallax in Altitude from Requisite Tables page 3, 4, 5; with this & the Distance take the Seconds from large Table IV. Also with Number C & the Distance, take the Seconds from the same Table IV; & the Difference of these Seconds is F.

5. From amongst the three hourly Distances in Ephemeris page 8, 9, 10 or 11, take two such Distances following each other, so that the true Distance of the Centres falls between them; then go on by the Formula till you have the Time at Greenwich; this is past noon for Greenwich.

6. From Ephemeris page 2. take the Sun's true Declination for the Hour at Greenwich; & when the Declination & Latitude are both North or both South, subtract the Declination from 90°; but in other Cases, add the Declination to 90°, to get the Polar distance. And subtract the Sun's Co-altitude from the Half sum to get a Remainder. Then go on by the Formula, 'till you have the Time at the Ship; this will be past Noon at the Ship in an Afternoon Observation, & short of noon in a Forenoon Observation.

7. In an Afternoon Observation, subtract one Time from the other, the Remainder is the Longitude; & it is West Longitude when the Time at Greenwich is greatest, but otherwise East Longitude. In a Forenoon Observation, add the two Times together, the Sum is the Longitude West, & it's Remainder to either 24 Hours or 360°, is East Longitude.

NB. These general Precepts, in several Parts of the Operation, may be shortened, by attending to the following Directions concerning each in particular.

Published according to Act of Parliament May 29th. 1782 by Samuel Dunn, Fleetstreet LONDON.

S. Dunn inv. & delin.

Supplementary LONGITUDE Instructions; By S. Dunn.

Of Preparations.

1. When the Sun & Moon's nearest Limbs have been observed; add 32′ to get the Rough Central Distance. Also, add the Sun & Moon's true Semidiameters, & Seconds for Moon's Altitude; to get L.

2. When the Star & Moon's nearest Limb have been observed; add 16′ to get the Rough Central Distance. Also add the Moon's true Semidiameter, & Seconds for Moon's Altitude, to get L.

3. When the Star & Moon's farthest Limb have been observed; subtract 16′ to get the Rough Central Distance. Also, subtract the Moon's true Semidiameter, & Seconds for Moon's Altitude, to get L.

Of Contractions.

1. In taking out the Number from large Table I, the nearest whole Degrees may be used in the most uſual Cases.

2. When the Number falls above or near the Crooked Line in large Table I, you need not find the Numbers A, B; but take from large Table III, the Seconds that are to be added to Number L, to give Number D.

3. When the Sun or Moon's Altitude is very small, the Refraction should be taken from the Altitude, before it is written in the Formula, next after the Horizontal Parallax.

4. In computing the Time at the Ship; the third Number or Sun's Co-altitude, is that of the Altitude leſsened both by Dip & Refraction.

Of Operations.

1. The Observations should not be made when the Sun or Moon are very near the Horizon. If the Moon is very near the Horizon, Proportional Parts should be used in large Table I.

2. Four Places of Logarithms with Index, are used, till the last Coſine; then the fifth Figure is 5 when 1 remains, & 0 when 0 remains.

3. C must not be added to D, unleſs the 1st Arc is least of the two Arcs, & at the same time D is leſs than 90°. In other Cases, subtract C from D.

Of Observations.

1. In observing for Longitude only, without use of a Watch, the Sun should not be very near the Meridian; then Observations will determine Latitude. Also, when the Moon is near the Meridian, Observations will determine Latitude.

2. When the Sun is far à Meridian & not near the Horizon, Observations are best for the Time & setting a Watch.

3. In the Night, the Watch shews Time at the Ship. When no Watch is used in the Night, the Right Aſcension of Sun & Star, compared with the Star's distance from the Meridian, either past or short of it, gives Time at the Ship. In this, the Chart of Zodiacal Stars is useful.

4. The Stars of first Magnitude out of the Zodiac, are useful for Time at the Ship; such as Capella, the principal in Orion, Canopus, Sirius, Procyon, Lyra. And so may Venus, Mars, Jupiter & Saturn.

5. The same Stars & Planets may be used for Latitude by Meridian Altitudes, Elapsed Time, & otherwise.

6. The principal Stars used in the Lunar Method are, Aldebaran, Pollux, Regulus, Spica, Antares, Aquila, Fomalhaut. The others are, Capella, Orion's Sirius, Procyon, Canopus, Arcturus, Lyra; the Bears, Ship & Croſs.

Published according to Act of Parliament May 29th. 1782 by Samuel Dunn, Fleetstreet London.

S. Dunn inv.t & delin.t

A New and Easy FORMULA for the LONGITUDE by SUN and MOON. By S. Dunn

Central Dist. Hours at Greenw. ° ′ ″

☉ & ☽'s Limbs observed.
☉'s true Semidiameter.
☽'s true Semidiameter.
Parts for ☽'s Altitude.

Observed dist. of Centres. =L

Least Alt. Centre clear.
Greater Alt. Centre clear.
Parts by Top & Side Tab. 1 2.
Dist. Centres Co. ar.

A = ″ Common Logar^{m}
B = Parts in Tab. II. add if the Dist. is above 90°.

=
add L=
D=

Hor^{l} Par^{x}. Propor^{l} Log^{m}
☉'s Altitude. Co Secant
Number D. Sine

1st Arc Propor^{l} Log^{m}

° ′ ″

Hor^{l} Par^{x}. Propor^{l} Log^{m}
☽'s Altitude Co Secant
Number D. Tangent

2^{d} Arc Propor^{l} Log^{m}

C = Add the Arcs if D. is above 90°.
D = Add C to D if 1st Arc is least & D is under 90°.

E =
F = Last Corr^{n} add if D. is under 90°.

P = True Dist. of Centres.

° ′ ″ ° ′ ″

Hours
Hours

Diff.
1st Prop^{l} Log^{m}
2^{d} Prop^{l} Log^{m}

D° Hours
P

Diff.
2^{d} Prop^{l} Log^{m}

Diff. of Log^{s}. in Prop^{l} Log^{s} H ′ ″
1st Hours add

Time at Greenw.

° ′

Co. lat.
à Pole
Co. Alt.

Co. ar.
Co. ar.

2)

½ Sum Sine
Rem^{r}. Sine

° ′

2)

Arc Co. Sine

H ′ ″

15) 2 (à Noon

H ′ ″

Time at the Ship
Time at Greenw.

° ′

Ship's Longitude or

The Co. ar. Sine, Tangent, &c. of Degrees when more than 90 is that of the Supp^{t}. to 180°. The Co. ar. is Co Sec. less 10 in the Index. In this Formula, when Addition is not to be made subtraction must. For correct Time, at the Ship, see my New Epitome of Navigation.

S. Dunn delin^{t}.

Published according to Act of Parliament, Nov^{r} 17th 1777. by Samuel Dunn, Maiden Lane, Covent Garden, London.

A Formula for the LONGITUDE having the Ephemeris & Common Tables of Logarithms By S. Dunn Teacher of Mathematics LONDON.

☉ or * à I.^{t} ☽ Alt I.^{t} ☉ Alt. I.^{t} Rough Time H. Lat.

Nearest Limbs. ° ′ ″
☉ or * à ☽ Limbs obs.^{d}
☉ Semidiam.^{r} p. 3
☽ Semidiam.^{r} p. 7
Parts for ☽ Alt.
Sum is D =
☽ Altitude Dip & Semid.^{r} clear'd.
☽ Coalt. co. ar.
D co. ar.
☉ or * Coalt.
2)
½ Sum Sine
Remain Sine 2)
Co. arch Sine
2
M =
☽ Co. alt Sine
″ ☽ Hor. Par.^{x} Log.
☽ Par.^{x} Alt. Log.
☽ Refraction sub.
Difference Log.
M = Co. sine
= A Log.

Farthest Limb ° ′ ″
* à ☽ Limb
☽ Semid.^{r}
Parts for ☽ Alt.
Sum sub.
Remain.^{r} is D =
☉ or * Alt. Dip & Semid.^{r} clear'd.
☉ or * Coalt. co. ar.
D co. ar.
☽ Coalt.
2)
½ Sum Sine
Remain. Sine 2)
Co. arch Sine
2
S = Co. sine
″
☉ Refraction
☉ Par.^{x} in Alt.
Difference Log.
B = Log.
A = sub. if M is under 90°.
B = add if S is under 90°.
C = is
D =
E =

add

Hours ° ′ ″
= first Hour & Distance in Ephem.^{s}
= second ditto.
ditto
Diff. = = ″ Log.
=
E = 3 4314
Diff = Log.
Sum
° ′
= Log.
Add first Hours in Degrees
Time at Greenwich in Degrees.
add
add

° ′ ″
Co. latitude co. ar.
Polar dist. co. ar.
Co. altitude
2)
½ Sum Sine
Remain Sine
Co. arch Sine
2
Aft.^{r} noon
Bef. noon
Time at the Ship
Long.^{d}

For ☽ Altitude °	Parts ″	For ☽ Altitude °	Parts ″
10	2	40	10
15	4	50	12
20	6	60	14
30	8	80	16

For ☉ Altitude °	allow ☉ Par. in Alt. ″
30	7
40	6
50	5
60	4
70	3
75	2

N.B. 1.st Rough central Distance shews the rough Hour at Greenwich & thereby the ☉'s Declin.^{n} is had Ephem. p. 2, (the ☉'s Semid.^{r} is p. 3.) the ☽'s Semid.^{r} & Hor. Par.^{x} p. 7. 2.^{d} Co. ar. is Cosecant less 10 in the Index. 3.^{d} Co. ar. or Sine &c. of more than 90° is of the Remain.^{r} to 180°. 4.th Refraction to be taken from the truest Tables. 5.th When you do not add subtract. 6.th Co. alt subtracted from ½ Sum gives Remainder. Polar Dist. is Decl.^{n} subtracted from 90°. if Decl.^{n} & Lat. alike, else added to 90°. 7.th If Time at Greenwich & at the Ship are both before or afternoon, their Difference is the Longitude; else it is what they are apart. 8.th Observe for Time at the Ship when ☉ is not near the Meridian. 9.th Reasons at large are in Astronomy p. 185 & Longitude at Sea p. 90. 10.th Latitude is found at any Time of the Day by the common Logarithms, as published by the Author, which see.

S. Dunn inv.^{t} & delin.^{t}

Published according to Act of Parliament, March 27.th 1779. By Samuel Dunn Maiden Lane Covent Garden, LONDON.

18

A. New FORMULA for Latitude, Time & Azimuth; having Sights of Sun, & Elapsed Time; By S. Dunn.

For Alt. far à Merid.		° ′ Account	By Latitude.		° ′ Correct.	For Alt. far à Merid.	
.	Co.ar.	.	Co.lat.		.	Co.ar.	.
.	Co.ar.	.	Polar dist.		.	Co.ar.	.
.		.	a=Co-alt.		.		.
.	2)	.		2)	.		.
2) .	Sine	.	½Sum		.	Sine	2)
.	Sine	.	Remʳ.		.	Sine	.
.	Coſine	.			.	Coſine	.
		. 2 .			. 2		.
.		.	= t	t =	.		
		.	= Q	Q =	.		
.	Sine	.	= T	T =	.	Sine	.
.	Coſine	.	= F	F =	.	Coſine	.
.	Sine	.	= G	G =	.	Sine	.
.	Sine	.	= F	F =	.	Sine	.
.	Secant	.	= G	G =	.	Secant	.
.	Coſine	.	= A	A =	.	Coſine	.
.	Sine	.	= N	N =	.	Sine	.
.	Secant	.	= G	G =	.	Secant	.
.	Coſine	.	= D	D =	.	Coſine	.
		.	= A	A =			
		.	= B	B =			
add if P is under 90°, elſe sub.		.	= C	C =		add if P is under 90°, elſe sub.	
		.	= D	D =			
Zenith dist.	.		= E	E =		Zenith dist.	
Declination			= F	F =		Declination	
Latitude						Latitude	

	°	′ For Alt. far à Merid.
Co-lat.	.	Co.ar. .
Co-alt.	.	Co.ar. .
½Sum	.	Sine .
Remʳ.	.	Sine .
	.	2) .
	.	Coſine .
	. 2	
		Azimuth far à Merid.
		For Alt. near Merid.
Co-lat.	.	Co.ar. .
Co-alt.	.	Co.ar. .
½Sum	.	Sine .
Remʳ.	.	Sine
		2)
		Coſine
	. 2	
	.	Azimuth near Merid.

1st. Q is the Elaps'd Time measd. by Watch.
2d. Co—, or Compt. is Remr. to 90°.
3d. When Lat. & Decln. alike, ſub. Decln.
from 90°. Elſe, add Decln. to 90°, to get
Polar dist. 4th Log. of more than 90°.
is Log. of Suppt. to 180°. 5th. Co-ar. is
Coſecant leſs Index 10. 6th. F is Decln.
& N Alt. near Merid. B is Co-decln.
7th. t & T, correct; are Times from Meridn. &
on one Side when t exceeds Q; elſe not.

N.B. If two Stars are used; Q is the Diff. of their Rt. Aſcenn. or Equatorial Distance.

Published according to Act of Parliament May 29th. 1782 by Samuel Dunn, Fleetſtreet London.

S. Dunn inv. & delin.

A New Formula for Latitude & Longitude, having Sights of Sun & Moon, or Moon & Stars; By S. Dunn.

For Alt. for a Merid. ° ′

Co.ar. . . Co.lat.
Co.ar. . . Polar dist.
a = Co alt.
2)
2) Sine ½ Sum
Sine Rem.^{r}
Cosine
2
= t
= Q
Sine = T
Cosine = F
Sine = G
Sine = F
Secant = G
Cosine = A
Sine = N
Secant = G
Cosine = D
= A
= B
add if P is under 90°. else sub. = C
= D
Zenith dist. = E
Declination. = F
Latitude

Q = El: Time. F = ● Decl.^{n}
N = Alt. near Merid. B = Co-Decl.^{n}

° ′ ″ Altitudes.
● ☽
Dist. Limbs.
Rough Central dist.
Rough Hour
● & ☽ Limbs obs.^{d}
● true Semidiameter.
☽ true Semidiameter.
For ☽ Altitude.
L = Obs.^{d} dist. Centres.

Least Alt = }
Great. Alt = } Table I. 2
L = Co.ar.
A = Common Log.
B = Table II.
is =
L = add
D =
☽ Hor Par.^{x} = Prop.^{l} Log.
● Alt = Cosecant
D = Sine
1st Arc = Prop.^{l} Log.
☽ Hor Par.^{x} = Prop.^{l} Log.
☽ Alt = Cosecant
D = Tangent
2^{d} Arc = Prop.^{l} Log.
C = add Arcs if D exceeds 90°.
D = add C to D, only when 1st Arc is least, & D is under 90° else sub.
E =
F = add if D is under 90°.
P = True distance Centres.

Distances.
° ′ ″
Hours
Hours
1st Diff. 1st P.^{l} Log.
Hours
P
2^{d} Diff. 2^{d} P.^{l} Log.
1st P.^{l} Log.
h ′ ″ Rem.^{r}
1st Hours add
Time at Greenwich.
° ′
Co-lat. Co.ar.
Polar dist. Co.ar.
● Co-Alt.
2)
½ Sum Sine
Rem.^{r} Sine
2)
Cosine
2
h ′ ″
15)
Time at the Ship
Time at Greenwich, past noon.
° ′
Longitude

S. Dunn inv.^{t} & delin.^{t}

Published according to Act of Parliament May 29th. 1782 by Samuel Dunn, Fleetstreet London

A New & Easy FORMULA for LONGITUDE & LATITUDE having Sights only: By S. Dunn.

° ′ ″ Altitudes.
☉ ☽
Dist. Limbs.
Rough Central dist.
Rough Hour
☉ & ☽ Limbs obs.^{d}
☉ true Semidiameter.
☽ true Semidiameter.
For ☽ Altitude.
L = Obs.^{d} dist. Centres.
Least Alt =
Great Alt = Table I. 2.
L = Co. ar.
A = Common Log.
B = Table II.
is =
L = add
D =
☽ Hor. Par.^{x} = Prop.^{l} Log.
☉ Alt. = Cosecant
D = Sine
1st Arc = Prop.^{l} Log.
☽ Hor. Par.^{x} = Prop.^{l} Log.
☽ Alt. = Cosecant
D = Tangent
2^{d} Arc. = Prop.^{l} Log.
C = add Arcs if D exceeds 90°.
D = add C to D, only when 1st Arc is least, & D is under 90°. else sub.
E =
F = add if D is under 90°
P = True distance Centres.
Hours
Hours
1st Diff. 1st P.^{l} Log.
Hours
P
2^{d} Diff. 2^{d} P.^{l} Log.
1st P.^{l} Log.
h ′ ″ Rem.^{r}
1st Hours add
h ′ ″ Time at Greenwich.

° ′
For Alt. far à Merid.
Co. ar. Co. lat.
Co. ar. Polar dist.
a = Co. alt.
2)
Sine ½ Sum
2) Sine Rem.^{r}
Cosine
2
= t
= Q
Sine = T
Cosine = F
Sine = G
Sine = F
Secant = G
Cosine = A
Sine = N
Secant = G
Cosine = D
= A
= B
add if P is under 90°, else sub. = C
= D
Zenith dist. = E
Declination. = F
Latitude
Co. ar. Co. lat.
Co. ar. Polar dist.
Co. alt.
2)
Sine ½ Sum
2) Sine Rem.^{r}
Cosine
= t
= Q
= T
h ′ ″
Time at Ship = t.
Time at Ship = T.
Time at Greenw.
Longitude.

Published according to Act of Parliament June 29th. 1782 by Samuel Dunn, Fleetstreet London.
S. Dunn inv.^{t} delin.^{t}